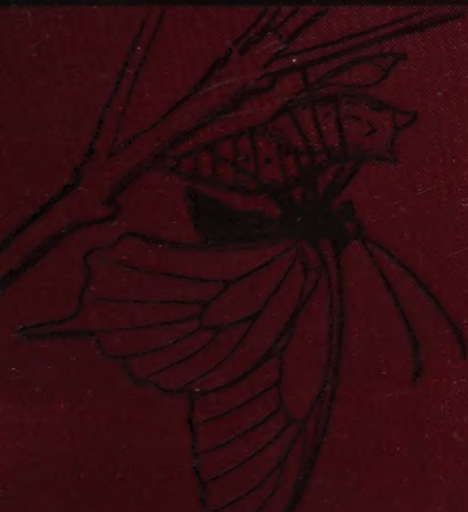
ELEMENTARY STUDIES IN INSECT LIFE



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ELEMENTARY STUDIES

IN

INSECT LIFE

BY

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CRANE & COMPANY, PUBLISHERS
TOPEKA, KANSAS
1903

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PREFACE.

Natural science studies are essentially studies of things, not books. The teacher in preparing a course of instruction must be governed largely by the material procurable. Work in marine biology can never be properly conducted away from the seashore, nor tropical life thoroughly presented in the temperate zone. In the study of animal life, insects present a fertile field. They outnumber all other forms, and are ever accessible. Under observation in their native haunts, or, in many cases, surrounded by artificial conditions, they conduct themselves naturally. The study of insects has therefore come to form a prominent part of zoölogical instruction.

This book on insect life is divided into two parts. Part I deals with the development of insects and their relations to their surroundings. Part II is devoted to Methods, Equipment, and Laboratory Exercises. The laboratory exercises consist of elementary work in the development, structure, function, and systematic arrangement of insects. The two parts are intended to be taken together. For example, in the laboratory exercises on metamorphosis, the detailed account of the life histories in Part I furnishes additional suggestions on points to be observed; the discussion of the special sense accompanies the anatomical work; the chapter on wealth of insect life amplifies the schemes of classifica-

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tion; and so on. The sequence of the work will be determined largely by the season of the year. Life histories and ecology will naturally be confined to spring and fall. During the winter months anatomical work can be well conducted upon material previously preserved.

The aim of the book has not been to familiarize the student with a number of isolated facts. It has been the endeavor to induce the student to become acquainted, through personal observations in the field and laboratory, with some of the important biological problems as presented by insects. Insects exist in certain given shapes, and in great or few numbers. There are reasons for such conditions,— causes which, wherever possible, the student should be led to see. Insects affect one another; they bear certain relations to physical conditions, and to other forms of life, both plant and animal. They affect man himself. These interrelations are subjects to be kept in view.

Insect life furnishes many practical subjects for nature-study lessons. Things that live and move elicit the interest and attention of pupils. Nature-study, to have an educative or disciplinary value, must not stop with superficial or passing observations. The educative value derived from nature study does not consist in the number of facts imparted, but in the development of the ability to acquire knowledge through careful and independent personal observation. The pupil at a glance will see that a caterpillar has come out of the egg, the caterpillar has changed to a chrysalis, and later that a butterfly has emerged from this chrysalis.

In truth, the pupil may have known this before coming under the teacher's guidance. A repetition with no addition will tend to dull the interest. The pupil should be encouraged to see that much remains to be observed. The author believes that there is material in this book which will meet the requirements of nature-study along the lines represented. This opinion is strengthened by the fact that teachers who have pursued this work under the author's direction have afterward used it successfully in the nature-study lessons in the lower grades of the public schools.

The illustrations have received special consideration. In places they supplant the text. For example: Following the account of the life cycle of the butterfly, a day-flying form, there are twenty-one figures illustrating the stages of growth and development of a moth, a night-flying form, belonging to the same group. It is believed that this manner of presenting the characteristic differences will tend to induce personal observations on the developing forms themselves.

The colored plates, and drawings where not otherwise credited, are the work of Miss Ella Weeks, to whom the author wishes to express his obligations. These were all drawn from nature or mounted specimens, and were originally prepared for this work with the exceptions of figures 153, 154, 156, 158, 159, from articles by the author in the Kansas University Quarterly; and figures 112, 116, 117, 171, 172, 193–207, 209–211, from contribution No. 65, a department publication by the author. Figures 50, 108, 168, 170, and 180 are photographs from department negatives. The

remaining photographs, not accredited, have been photographed from nature or preserved specimens by the author for this work.

The author wishes to express his thanks to Miss M. E. Wise for the drawings which bear her name, to Professor M. V. Slingerland for photographs, to Professor E. A. Birge for the use of electros for figures 56 and 58, to Mr. M. B. Waite for the use of electros for figures 72–84, to the Century Company for the electro for figure 65, to the Goulds Company for electros used for producing figures 231–234. Specific acknowledgment accompanies each of these illustrations.

Material assistance in the preparation of this work has been given by Professor W. C. Stevens, who has kindly loaned a number of photographs, and has read chapter VII both in manuscript and proof; by Professor V. L. Kellogg, who has made valuable suggestions; by Dr. S. W. Williston, who has read the proof-sheets on the classification of Diptera; and by Professor C. E. McClung, who has very kindly read the entire book in proof form. An expression of the author's appreciation is but a slight token in recompense for the value of these courtesies.

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ELEMENTARY STUDIES IN INSECT LIFE

CHAPTER I

THE CYCLE OF LIFE

THE passage of nearly every insect from the egg stage to maturity is marked by a series of changes,—gradual in some, abrupt in others. The insects which change gradually maintain the same general appearance and structure throughout life. The insects with abrupt changes pass through stages in which forms are assumed very unlike and not easily associated. These striking and radical changes which take place in growth and development are termed metamorphoses.

Incomplete Metamorphosis.—The young grasshopper escaping from the egg has much the same form as its parent, and the casual observer easily recognizes it as a grasshopper, the only marked difference being that it is smaller and wingless. In time, however, the full size is attained, and with it proportionate wings. The growth (increase in size) and development (change in form) of this insect go on without any abrupt changes. Insects which mature in this way are said to have an

incomplete metamorphosis, and in the immature stages are spoken of as nymphs.

Complete Metamorphosis.— It is sometimes difficult to associate the identity of a bright-winged butterfly with that of some ugly caterpillar. Nevertheless, every butterfly was once a caterpillar, and not infrequently the most repulsive caterpillar becomes the most attractive butterfly. The honey-bee comes from a white grub, the house-fly from a maggot. Insects which develop in this manner are said to have a complete metamorphosis. They emerge from the egg in a worm-like form called the larva, or the larval stage; growing to considerable size in this form, they pass into a very dissimilar stage, the chrysalis or pupal stage, in which the insect is quiescent and non-feeding, and during which the fully matured insect is developed.

Molting.— All insects, during their growth and development from the egg to maturity, undergo at certain periods a process commonly known as molting. The outward indication of this process consists in the shedding of the skin. These changes are not alone for the discarding of unyielding or chitinous coverings to permit enlargement in bodily size, but are as well physiological processes, attended by marked changes in tissues and organs.

Insects with a complete metamorphosis appear in four forms: the egg, the larva, the pupa, and the adult; while in those with incomplete metamorphosis there are but three forms: the egg, the nymph, and the adult. In order that these two methods of insect growth and development may be more fully understood, a type of each has been selected for illustration.

The Life of a Grasshopper.— Fashions and changes in dress are not limited to people alone. In the cornfields or in the protective shadow of some tall weeds by the roadside, or probably in your own garden, the grasshoppers are laying aside old garments for bright new ones. This is happening every day during the warm summer months. These changes are made, because, like children, they have outgrown their clothes. In other words, the skeleton of the grasshopper, as we shall see later, is rigid and surrounds the body, acting as an armor against the rough blades of grass and the attacks of other insects.

FIG. 1. The yellow grasshopper (*Melanoplus differentialis*), female. From photograph.

FIG. 2. The yellow grasshopper (*Melanoplus differentialis*), male. From photograph.

The grasshopper,* which has been selected to illustrate incomplete metamorphosis, spends the cold winter days as an embryo, in an egg such as shown in Figure 3, along with a hundred or more similar eggs in a pod laid in the ground the previous fall by the mother insect. These eggs quietly await the warmth of spring to bring them to life.

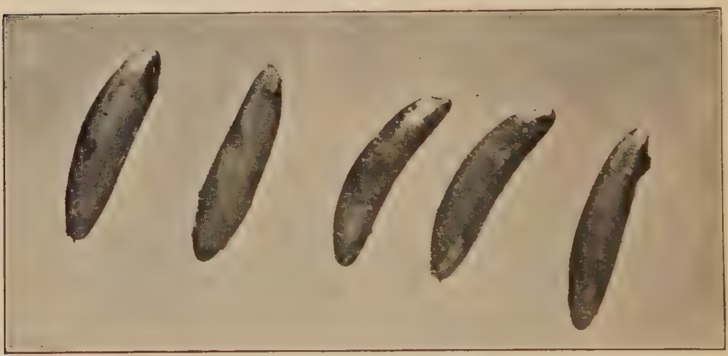

FIG. 3. Eggs of the yellow grasshopper (*Melanoplus differentialis*). Enlarged.

The young insect soon works its way to the surface, where food is sought for strength and growth; and as it grows it assumes new forms and new garments. This change of clothing, or shedding of skin, more properly called molting, takes place a number of times during its youth. The most interesting molt is the last one, the one in which the grasshopper brings out fully developed wings from the wing-pads in the skin which is being cast off. The observations recounted in this chapter were made in a cornfield; and from sketches taken

* The yellow grasshopper, *Melanoplus differentialis.*

FIG. 4.

DESCRIPTION OF FIG. 4. Various stages of the last molt of the yellow grasshopper (*Melanoplus differentialis*). *1*, nymph just before the breaking of the skin along back of thorax; *2*, nymph beginning to come out; *3*, mature insect dropping to the ground; *4*, cast-off skin, still clinging to the leaf; *5*, grasshopper climbing up, spreading wings to dry, and getting ready to eat; *6*, fully developed grasshopper on corn-stalk.

at that time, Fig. 4 has been constructed to illustrate this interesting transformation.

Up to this time in its growth the grasshopper is spoken of as being in the nymphal stage. The plate shows the transformation from the nymph to the adult, or as we might say, from youth to maturity. The full-grown nymph ceases to eat, and with the head almost invariably downward, the antennæ drooping, fastens its claws firmly into the stalk or blade and remains quiet for a short period, during which it can be handled without being disturbed; a pulsating motion begins in the center of the back of the thorax; this increases until the whole thorax moves up and down; soon the skin splits along the back from the top of the head to a line crossing the base of the front wings; the upheaving action of the thoracic muscles continues until the body drops to the ground, leaving the nymphal skin clinging to the leaf; the antennæ lie on each side of the face, and are thus drawn out from under the body; the wings come straight out of the pads, narrow and much wrinkled. They are about five-eighths of an inch long when the insect falls to the ground. The insect now is pale, almost colorless. Inside of an hour, depending upon the weather and time of day, the wings attain their full length, one inch to one and one-quarter inches, and the characteristic colors appear. The legs are not brought into use in discarding this skin. Frequently the claws of the old skeleton break away from their attachment, and the insect falls to the ground. This in no way interferes with the transformation. The insect, when free from the old covering, though its limbs are quite soft and unable to maintain its weight well, crawls to

some secluded place, where it awaits the hardening of the body-wall and the expansion of the wings. Before this is fully completed the insect again begins eating.

The morning hours are the best times for you to look for this change, though frequently it occurs in the late afternoon. If in your rambles you observe a nymph which does not jump away when you come near it, and which does not sit erect but is rather drooping, watch it and you will very likely be rewarded by seeing this interesting change.

FIG. 5. Nymph of *Melanoplus*, first stage. After Emerton.

FIG. 6. Nymph of *Melanoplus*, second stage. After Emerton.

FIG. 7. Nymph of *Melanoplus*, third stage. After Emerton.

FIG. 8. Nymph of *Melanoplus*, fourth stage. After Emerton.

FIG. 9. Nymph of *Melanoplus*, fifth stage. After Emerton.

FIG. 10. *Melanoplus* adult.

This grasshopper of which we are speaking has a variety of tastes and seems to know where to find good

things, but if these are not at hand it will satisfy itself with such fare as can be procured. For instance, it wisely climbs up a tree and eats the fruit before disturbing the leaves of the tree. If fruit or cereals or garden vegetables are not at hand, it can make a very good meal upon sunflowers. These grasshoppers, like many other insects, are creatures of habit, and their days are spent generally in about the following way: Before sunrise the nymphs and adults begin to climb to the tops of weeds or fence-posts, and remain there till about ten o'clock. If the article upon which they rest is edible, they amuse themselves by nibbling away. About ten o'clock in the morning they descend, and feed lower down. During the middle of the day they hop about, generally moving in some one direction. The instinct of fear is not wanting even among grasshoppers, and the smaller ones always give place upon the approach of the older ones. About three o'clock in the afternoon these insects take some elevation, much the same as they do in the morning, to remain until sundown and sometimes even throughout the night. Grasshoppers are strongly influenced by the weather. On cool and cloudy days they are sluggish and inactive; on warm and sultry days they live an active life.

Thus they spend the time until the fall of the year. Then the females deposit their eggs, which are to continue the species. It is not difficult during September and October to observe the females ovipositing. When they have begun, they are not easily disturbed. A female in quest of a suitable position for placing the eggs generally moves slowly about for some time, testing the ground over which she passes. During this time the tip

of the abdomen is turned downward, and, stopping momentarily, the ovipositors (Fig. 198, *o*) are applied to the ground. Some, however, begin to dig and complete the work where the first attempt is made. Small elevated spots on the surface appear to be much chosen. Frequently these little hillocks are not noticeable until marked by a locust digging into the crest. From Figure 12, *g*, *g'*, *g''*, it is evident that for oviposition the same place is sometimes chosen by several grasshoppers. Sandy soil, when present, seems preferable.

FIG. 11. Vertical section of ground, showing two egg-pods of yellow grasshopper in position in ground at right; female yellow grasshopper digging hole in which to place her eggs; longitudinal section of egg-pod at left, showing position of eggs in pod. Drawn from life.

A suitable place chosen, the locust forces a hole in the ground by means of the two pairs of horny-tipped ovipositors at the end of the abdomen. These are opened and closed and the full weight of the body is brought to bear on them. In this way a receptacle is made for the eggs, often in extremely firm ground.

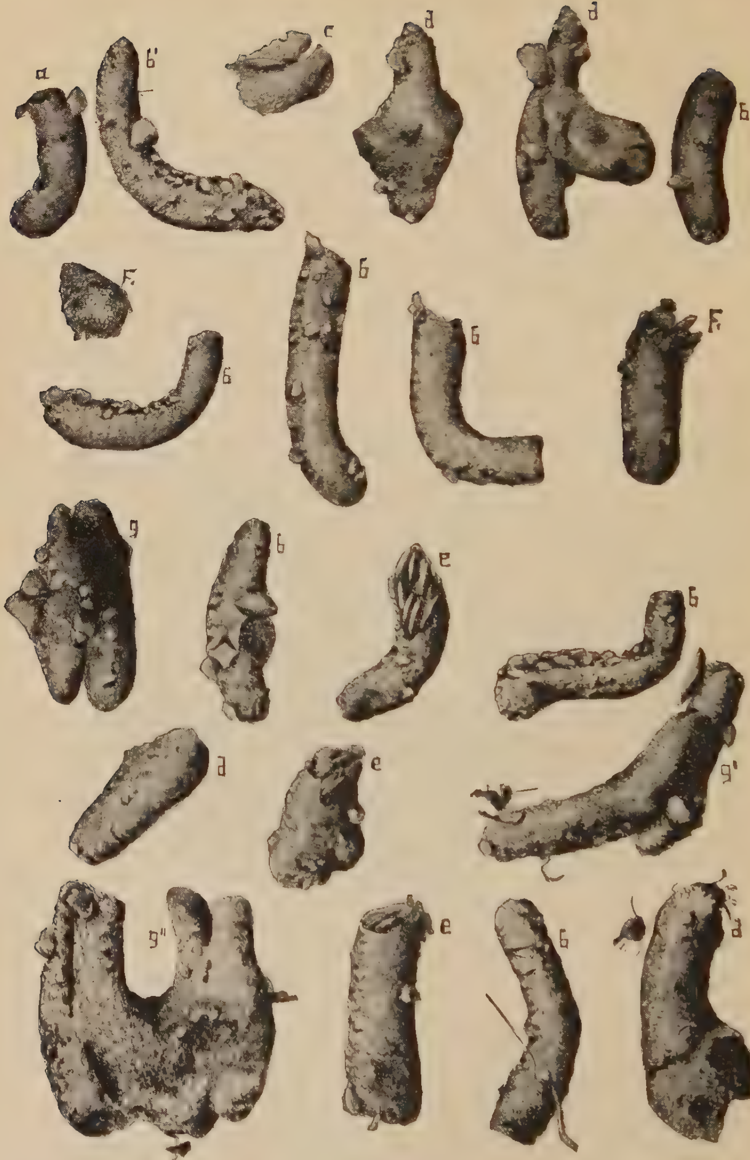

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FIG. 12.

Description of Fig. 12.

Egg-pods of *Melanoplus differentialis* taken from a sandy soil, showing variations in shape. *a*, pod with top broken off; *b* and *b′*, pods made of sand with larger grains of sand or stone adhering; *c*, small portion of outside shell broken off; *d*, specimens made of sand and dirt with stones or clods of dirt firmly fixed to the side; *e*, specimens broken off near the top; *F*, shows an unfinished pod — the grasshopper was disturbed while depositing eggs, and the pod was taken in this unfinished state; *g* and *g′*, specimens taken, showing two pods firmly fixed to each other, composed of sand; *g″*, four pods of sand and dirt, with small stick and dead rootlets adhering; *Fr*, cross-section of top of pod, showing honeycomb structure made by the sebaceous fluid when dry.

Each egg is preceded by a light-colored mucous fluid. Part of this fluid passes through the walls of the cavity and causes surrounding particles of dirt, sand, and in some cases small clods (see Figure 12, *d*) to adhere; so that the pods when removed from the ground are protected first by a coat of this sticky substance and then by an outer layer composed of particles of surrounding earth. This forms a brittle crust which, when pressed, often scales off, as shown by Fig. 12, *c*. If the ground is firm, the walls of the pod are generally broken away when the earth is disturbed, thus exposing the naked eggs.

This substance before hardening is quite plastic; after hardening it is somewhat fragile. It is insoluble in water, and thus protects the eggs from rain or snow. When the eggs are all deposited the female covers them with a small amount of this sebaceous fluid. This hardens into a honeycomb structure, as shown in cross-section of top of pod, *Fr* in Fig. 12. The cross-line near top of pod, at *b′* in Fig. 12, shows depth of covering. The whole pod is finished about one-quarter inch below the surface of the ground, and the ground covered over, leaving no trace of work, as shown on ground surface in Fig. 11. The arrangement of eggs is shown in the longitudinal section of the pod in the foreground of Fig. 11. The number of eggs in a pod is about 100.

Eggs placed in the ground at this late season, the fall of the year, will not receive heat enough to hatch, so that the species passes through the rigorous period of winter in the egg stage. During the first warm

month of spring the eggs hatch, and the cycle of grasshopper life begins to repeat itself.

The Butterfly.— Butterflies are and have been fertile subjects for the writer's pen and the artist's brush. The velvet-winged butterfly is a symbol of the light, the careless, the free, and the beautiful. Let us see whether "it toils not, neither does it spin" can be said truly of the butterfly. For study let us take a general favorite, the black swallowtail.[1] The female butterfly seeks her nourishment from the apple and thistle blossoms, but when the time has come for egg-laying she sails to some neglected corner in the garden, or shady, unfrequented dell where the wild parsnip[2] or the wild celery[3] grows, or some other plant of this family.[4]

It was during the first days of June we watched her. She placed her pale yellow eggs singly on the small flower-stems of the cluster.

FIG. 13. Egg of the black swallowtail on flower-stem of wild parsnip. Enlarged.

These globular eggs are about one-twenty-fifth of an inch in diameter, and soon become brownish gray, soft and moist. Such conditions indicate that hatching is about to occur. (See frontispiece.) At this time, with the aid of a hand-lens, motion may sometimes be perceived inside of the semi-transparent shell. A little black point appears through the shell: it is the tiny mandibles eating their way, making a round hole sufficiently large for the little dark caterpillar, wriggling and twisting, to escape.

[1] *Papilio polyxenes* Fabr.
[2] *Pastinaca sativa* L.
[3] *Peucedanum fœniculaceum.*
[4] *Umbelliferæ.*

When first this larva measures itself upon the flower-stalk it is three-twenty-fifths of an inch long,— three times the diameter of the egg from which it came. After stretching itself and resting a moment it turns around and makes its first meal off its shell,— not prompted so much by hunger as by the protective instinct which leads it to endeavor to remove all traces likely to lead to its discovery by an enemy.

FIG. 14. Newly hatched caterpillar of the black swallowtail on flower-stem of wild parsley. Enlarged.

As it stretches itself out again, study it under the hand-lens. It has the normal number of segments, twelve besides the head. Each segment has six protuberances, and from each of these in turn grow five or six hairs, making in all a rather bristling little creature. The first three segments of the body, known as the thorax, have true jointed legs, each with a horny claw for grasping the supporting twig; the sixth, seventh, eighth, ninth and twelfth have each a pair of soft unjointed legs, or pads known as prolegs, aids in locomotion and in maintaining position "when the wind blows."

FIG. 15. Diagram showing normal number of segments in a caterpillar.

Its purposes, intuitions and instincts have been placed in verse.

Born, bred, with just one instinct,—that of growth:
Her quality was, caterpillar-like,
To all-unerringly select a leaf
And without intermission feed her fill,
Become the Painted Peacock, or belike
The Brimstone-wing, when time of year should suit;
And 'tis a sign (say entomologists)
Of sickness, when the creature stops its meal
One minute, either to look up at heaven,
Or turn aside for change of aliment.

Browning—"Red Cotton Night-Cap Country."

FIG. 16. Caterpillars of black swallowtail feeding on wild celery. Photographed from life.

During the first five or six days of its existence this caterpillar becomes three-fourths of an inch long, black or very dark brown, excepting a white band around the sixth and seventh segments. It now prefers the tender flowers, eating all the parts but the yellow petals, which drop off untouched. (See frontispiece.)

Throughout the caterpillar's growth at certain periods an interesting process occurs. It sheds the cuticular skin, an action frequently called molting. This generally takes place during the early morning hours.

For a long time the larva rests quietly, and the skin becomes like an old garment. Undulatory movements of the body headward, slow at first, then increasing, crack the skin around the neck; the caterpillar, pulling itself forward, pushing the skin backward, throbs and pulsates until the skin crumples up unbroken at the end of the body. The head is thrashed about from side to side, occasionally rubbing and striking the stalk, until the hood is discarded. From ten to fifteen minutes of its lifetime are required for each change in

FIG. 17. Caterpillars of black swallowtail about to molt. Photographed from life.

clothing. The caterpillar, with its new, whitish, almost colorless coat, rears up its head, remains nearly motionless for about an hour. This is time sufficient for the characteristic colors to develop and for recuperation. Prompted by the same instinct which caused it to conceal its shell-house, its first act now is to turn around and devour the old covering. The fasting, the exertion in eating the skin, every act of the whole performance tends to sharpen the appetite. It eats voraciously, not the tender flowers as before, but the seed-pods and large

stems and leaves. This caterpillar no longer requires a milk diet.

Its horns, present from birth, are now even more noticeable and their use is more readily discerned. For, when disturbed by any object other than one of its mates, the caterpillar projects its soft, fleshy, orange-yellow horns from behind the head. The position of the horns, their formidable appearance, and the act of protruding them, all tend to frighten away approaching foes. There still remains, as a last and most effective means of defense, a repulsive odor arising from these horns, sensible ten or twelve feet away. This offensive odor saves many a caterpillar from the destructive beaks of insectivorous birds.

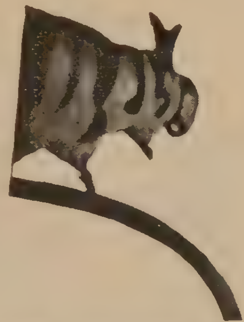


FIG. 18. Caterpillar of black swallowtail protruding horns (*osmateria*) upon being touched by the finger. Photographed from life.

Sociability is not one of the characteristics of this immature butterfly. If one caterpillar encroaches upon the other's territory, violent displeasure is manifested by the dashing of the head from side to side. Never at such times are the horns protruded, nor is the offensive odor emitted. Why?

At about three weeks of age the larva has grown until it is about as many inches in length, has changed its skin five or six times, has discarded the tubercles and spines so prominent in the young thing just out of the egg. It is ready to become a chrysalis, a pupa, an in-

—2

active form before which we may stand, and, like Tennyson to the flower, say:

> "If I could understand
> What you are, root and all, and all in all,
> I should know what God and man is."

FIG. 19. Position of caterpillar of black swallowtail just before pupation. Slightly enlarged. Photographed from life.

This interesting caterpillar, thus far content to remain upon the plant where its parent placed it, now grows restless, leaves the seed-pods, descends the flower-stalk, sometimes forsakes the plant entirely. In any case it choses some secluded spot on a lower branch of its food plant, the dead limb of an adjoining tree, or a neighboring fence-board, as a place for its subsequent transformations. In the vivarium they adapt themselves to the circumstances. One we watched chose the wire screen of a breeding-cage, another the handle of a silver cup which held the food plant. In nature, however, these caterpillars seem to show a decided preference for slanting objects when selecting a location for pupation.

The changes undergone by a caterpillar in passing from the larval to the pupal stage have always excited much interest and elicited the closest attention of the observer. Words are inadequate to portray the transition. It must

be seen to be appreciated. The caterpillar begins to spin from its mouth fine white silken fibers, not unlike a spider's thread. The fore feet are brought into use a little in drawing out the thread to the proper length. A cushion about two-twenty-fifths of an inch in diameter is constructed of this material. Strengthening threads are woven over and about this pad, making it doubly secure in its position. To this cushion the body is firmly fastened by means of the last pair of prolegs. The caterpillar frequently tries its "hold" before fixing itself. Should the silken foundation not feel firm enough for the responsibility about to be imposed, the larva releases its grip, turns around and reinforces the cushion with additional fibers.

A firm hold is then taken with the anal prolegs; the caterpillar rests head upward, with the body slightly contracted. After a moment it turns the head and thorax to one side as far as possible, fastens a thread of silk to the supporting object; then, bending the head backward at almost right angles to the body, it carries the thread slowly by short jerks to the opposite side, fastens it securely, and brings back another thread in the same manner to the starting-place. This is repeated until fourteen or fifteen threads form a loop in front of the head. Into this the head and five segments of the body are thrust, allowing the band to slip into the groove between the fifth and sixth segments. The body now hangs head uppermost in the silken loop, with the caudal extremity clinging to the silken pad. The caudal extremity is the only part of the body in contact with the support. The caterpillar grows shorter, the segments appear swollen, the head curls forward. In this

FIG. 20. Caterpillar of black swallowtail about to shed the last larval skin. Enlarged to show "cushion" and "silken loop." Photographed from life.

FIG. 21. The developing chrysalis of the black swallowtail. Discarded larval skin, much wrinkled, still on lower part of body. Photographed from life.

state the insect remains suspended for from nineteen to thirty hours.

At the end of this resting period the whole body begins to contract, expand, and twitch; the skin has become thin, old, and almost imperceptibly begins to move backward, gathering in tiny folds; it breaks on the back along the median line of the thorax. The body movements increase, the central portion elongates, the thorax rests back heavily upon the silken loop. The whole covering, the feet, the head, all appendages are discarded from the posterior end, which is loosened momentarily for the purpose. The caudal end is again

thrust into the silken cushion, and there before our eyes the characteristic colors of the chrysalis appear,— at first green, in some cases remaining so throughout pupation, in others turning a protective wood-brown with a dash of frosty-white here and there.

This June generation has all experienced the wonderful transition before the month's end. Each is encased in a hard brown shell, a covering admirably adapted for the changes which occur during this quiescent period. This shell is protected at every point of probable contact by callous projections. Capable of no external motion, the pupa lies in a trance, as it were, for from ten to twenty days, according to the character of the weather,— warm weather favoring growth.

FIG. 22. Brown pupa-case or chrysalis of black swallowtail. Enlarged. Photographed from life.

When it is known, however, that the being enters this tenement as a caterpillar and comes forth by-and-by a bright butterfly, it is evident that great activity has existed within this shell. The hour when we are to see the butterfly is foretold by a duller color, the line markings become less distinct, the shell appears to be-

come moist; then the case gives way along the back, owing to the muscular contractions within, opening a way for the appearance of the black head and legs. Slowly and cautiously the legs become effective, and in a moment's time the smooth inner walls have permitted the escape of the delicate creature; cautiously it climbs over the old shell to the supporting twig, there to await the sun's strengthening action upon its four wrinkled, folded and limp wings. The body strengthens, the wings expand, the colors stand out, the life and courage increase, and it takes its initial flight. (Frontispiece.)

"Butterfly, good-by to your shell,
And bright wings speed you well."

FIG. 23. Empty pupa-case of black swallowtail, showing characteristic opening through which butterfly emerged.

This butterfly, in the form in which we have thus far studied it, had, during its caterpillar stage, a mouth with jaws fitted for masticating vegetable food. During this eating period sufficient nourishment was stored for pupation. Now this same individual, in adult form, a butterfly, no longer has the means nor the power for biting off bits of plant leaves. The butterfly, then, must obtain its food in another form. This it finds in the nectar of flowers. To enable it to reach the nectaries within the blossom, the butterfly is equipped with a long sucking-tube or proboscis. You will not readily perceive this when you first capture the butterfly, since,

while not in use, this tube is tightly coiled up in front of the head. The length of this sucking-tube in the black swallowtail is about three-quarters of an inch. With insect in hand, a careful examination of its parts will no doubt reveal the position and extension of this butterfly's mouth. As you might suppose, then, the swallowtail is a frequent visitor to the blossoms of flowers. It is fond of the nectar secreted by the thistle and apple, and has been known to visit the verbena blossoms to such an extent that flowers could not be obtained, since the butterflies in withdrawing their tongues pulled the flowers all to pieces.

They are low flyers, and when not disturbed wend their way back and forth about the meadows and pastures. If alarmed, however, they greatly increase their speed, darting here and there in a zigzag course. Self-preservation is no less manifest in this delicate form than in those animals of greater size and longer duration of life.

Six egg-shells from which young cecropias have hatched. The young cecropia emerging from the seventh. Photographed from life. (Enlarged.)

Young cecropia, first stage. Color, black. (Enlarged.) Photographed from life by M. V. Slingerland.

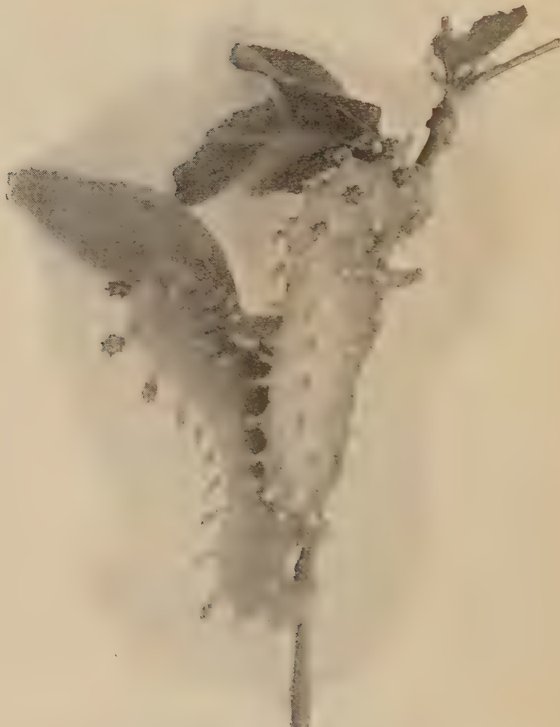
Young cecropia, second stage. (Enlarged.) Color, obscure yellow. Photographed from life by M. V. Slingerland.

THE LIFE OF A MOTH (*Samia cecropia*).

Young cecropia, third stage. (Enlarged.) Photographed from life by M. V. Slingerland.

Cecropia molting the fourth and last time — natural size. Photographed from life by M. V. Slingerland.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.



Oecropias after fourth moit — natural size. Photographed from life by M. V. Slingerland.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Cecropia, full grown—natural size. Color, dull green. Tubercles, blue on sides, yellow on back. The four large tubercles near head are reddish. Photographed from life by M. V. Slingerland.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Cecropia spinning its cocoon—natural size. Photographed from life by M. V. Slingerland.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Cocoon of cecropia. Photographed from life. $\frac{7}{9}$

Chrysalis of cecropia taken out of cocoon. Photographed from life.

Empty chrysalis from which cecropia moth has emerged. Both natural size.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Four stages in the emergence of cecropia from the cocoon. Photographed from life. $\frac{7}{9}$

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Cecropia just out of the cocoon. Photographed from life. ⅔.

Back and side views of cecropia a few minutes after emergence, showing the limp, moist wings beginning to develop. Photographed from life. ⅔.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Cecropia moth about half hour after emergence, wings almost fully developed, but still limp. Photographed from life. ¾.

Group of newly hatched cecropia moths in characteristic positions during the development of the wings. ⅝.

THE LIFE OF A MOTH (*Samia cecropia*).—CONTINUED.

Adult cecropia moth (female). ¾.

THE LIFE OF A MOTH (*Samia cecropia*).—CONCLUDED.

CHAPTER II

THE SPECIAL SENSES

Value of Sense Organs. — In animal life there arises with the development of the nervous system, the need of transmission of impressions from certain nerve centers to the muscles. This need is fulfilled by the means of motor nerves. External impressions are to be conveyed inwardly, to special nerve centers. This function is performed by the sensory nerves. In the simplest forms of life, such as the Amœba, the body of which is composed of but a single cell, special sensory organs are wanting. The outer part or surface is a general sensory organ. While the sensory phenomena of these primitive forms are not well known, it has been ascertained that they are sensitive to external stimuli, such as electricity, contact with other bodies, heat, and the actions of certain chemicals. Many are sensitive to light. As the scale of life advances, and animals become more complex, the sensory areas become more localized, and their functions more varied. When sensory nerves become grouped in one locality or organ of the body, for a special purpose, we call that location or organ, with its nerves, a sense organ. With this localization there comes also an increase in the power

of the sensibilities. In insect life we find the sense of touch, the sense of sight, the sense of taste, the sense of smell, and the sense of hearing.

The Study of the Special Senses.— Our impressions of the character of the world around us are based upon experiences gained through organs of special sense. We are acquainted with only those things which influence our senses, and so, in speaking of special senses, we are wont to consider them from our own standpoint. Therefore our study of the senses of those forms of life which cannot communicate their impressions directly to us, must be carried on by comparison with our own impressions. In ourselves, we are aware of five senses, namely: smell, touch, taste, hearing, and sight. In our classification of the senses of lower animals, we classify the senses of these animals accordingly as the actions of these senses compare with the physiological functions of our own. It is possible that other forms of life have other senses, but it is somewhat difficult for us to comprehend clearly the character of a sense which we ourselves lack. Dissections of special sense organs do not always give conclusive evidence as to the significance of the sense organs. For instance, it would be hard to tell, by cutting to pieces, whether a certain organ was used for tasting or smelling, or for either. Our conclusions are frequently based upon observations made upon the actions of certain special sense organs. Our present knowledge, then, of special sense organs has been gained by experiments with living forms, and by anatomical investigations.

The Sense of Touch.— If the soft surface of the tips of the palpi (labial and maxillary) of the grasshopper's mouth (Fig. 195, *e*, *g*) be examined under the compound microscope, little peg-like structures will be observed. These are connected with nerves which transmit sensations of contact, or touch. These organs derive their names from this function. While this sense is localized chiefly in the palpi, it is not confined to them alone. The antennæ also serve as tactile organs, but in a variable degree according to their forms, their development, and the habits of the species. Species of beetles without eyes find their way about by means of these antennæ. Our familiar long-horned beetles grope their way among the branches of trees, using their long antennæ for the purpose. Insects with long, filiform, many-jointed antennæ use them as feelers. Insects with short, stiff antennæ, with few joints, evidently do not use them as feelers, and so do not have the tactile sense of the antennæ developed in such a high degree. In many insects the extremities of the limbs also have nerve cells which convey impressions of touch. The membrane underlying the chitinous covering of insects is sensitive to touch, so that nearly every portion of the insect's body perceives contact with foreign bodies.

The Sense of Taste.—The sense of taste has to do with the determination of the character of matter presented as food, and so the organs of taste naturally lie in the vicinity of the mouth. Of the nerves of taste, some are to be found on the palpi of the mouth, situated with the tactile nerve cells, and others on the membranes of the mouth. This sense is very closely connected with the

sense of smell. These organs of taste are minute pits, hairs, or short peg-like structures which form the end of the gustatory nerves, and are most numerous on the membranes within the mouth. They are situated at a point where the food must necessarily touch them as it enters the mouth and passes down the throat.

The sense of taste is highly developed in bees. Observations upon the readiness with which bees use this sense can be made by placing on a large platter, accessible to bees, plain honey and honey mixed with substances likely to be unpleasant to bees. Ants have been drawn to honey in which there was morphine and strychnine. The smell of the honey attracted them, but the moment the honey touched their lips they ceased eating it. Neither in the antennæ nor anywhere outside of the mouth was there any organ which informed them of the unpleasant substances within the honey. An interesting experiment performed with wasps, was as follows: sugar was fed to them from day to day at a certain place, until they became accustomed to coming to that place for the sugar; powdered alum was substituted for the sugar. They had scarcely touched it when they drew back with most comical gestures, cleaning their tongues by frequently running them in and out and stroking them with their fore feet.

The Sense of Smell.— The antennæ perform dual functions. It has been shown in discussing the sense of touch, that the antennæ are tactile organs. The antennæ may be regarded also as the principal organs of smell. The nerve endings are similar to those of the nerves of touch, being pits or papillæ. The sense of smell is highly developed among insects. It is con-

stantly used. By the sense of smell, insects are enabled to discover food, to recognize their friends, avoid their enemies, and to seek their mates.

These various uses have been confirmed repeatedly by experiments. Certain carrion-eating beetles inclosed in a large box invariably sought out a small bit of decaying flesh within a bottle located in one corner. When the antennæ were covered with wax, so that the olfactory nerves were no longer sensible, the beetles no longer found the meat. Flies were attracted into a room by a piece of decaying meat. It seemed impossible to drive them away from the meat. These same flies paid no attention to the meat after they had been caught and their antennæ rendered insensible. The actions of the insects in other respects seemed normal, so that their indifference toward the meats could not be charged to any discomfiture from the temporarily insensible antennæ. Closely constructed boxes in which were inclosed certain species of female moths have attracted the males of this same species. The males of such

b *a*

FIG. 24. Heads of (*a*) male and (*b*) female Cecropia moths. Photographed on same scale, illustrating the greater development of antennæ in male moth. × 2.

species have been known to appear at the windows of rooms in which the females were in captivity. Now in these moths the antennæ of the males are highly developed. It seems undoubtedly to be the case that since the males could not see the females, they discerned them through the sense of smell. And this is further evidenced by the antennæ, the seat of smell, being more fully developed in the males than in the females.

In the growth and development of insects, we have found that at different stages the structure of the insect and the food habits are different. The butterfly has a long very slender tube through which it secures its liquid nourishment. It has no jaws with which to masticate the leaves of plants. The caterpillar which hatches from the egg of this very butterfly has jaws with which to eat. It has also specially formed tastes for certain plant tissues. If the eggs are deposited in places remote from the proper food plants the young caterpillars will starve, since they have no "taste" for other plants and will not eat them. The parent, then, must be able to recognize the proper food plants upon which or near which to deposit her eggs. Her sight, as we shall see presently, is imperfect, and does not clearly recognize the various forms in plants. She cannot taste the plant leaves, and in many cases there are no nectar-bearing blossoms to aid her. Plants give off characteristic odors, and it is upon these she evidently depends for the recognition of the plants furnishing proper nourishment for her young.

The Production of Odors.—Many caterpillars emit offensive odors. (See pp. 16, 17.) Certain insects, such as the well known "stink-bugs" (Fig. 45), give off, when

disturbed, disagreeable scents. These are given off for the purpose of protecting themselves by repelling inimical insects, and more especially other enemies, such as birds. There are, however, odors given off by insects, evidently intended solely for the benefit of other insects; that is, to render themselves by the possession of this odor attractive to other insects. Many of these odors are perceptible to us. Our monarch butterfly[1] (Fig. 48*a*), emits a slightly honeyed odor; the small blue butterfly,[2] common in spring, has an odor resembling crushed violet stems. The white butterfly[3] gives off a faint odor of syringa blossoms. These instances with many others show that many butterflies emit odors, apparently in most cases agreeable to us. These odors are emitted through minute canals found in very small scales of the butterfly wing. These scales are called scent scales. As far as our sense can perceive, some insects with well-developed scent scales emit no odors. It is evident, then, that the odors which they emit are beyond our perception, and that to such insects we must attribute an exceedingly delicate sense of smell. This statement is not difficult to accept, when, as before noted, the males of many species are able to locate, within a dwelling, entirely out of sight, females of their own species. They do not so much "walk by sight" as "fly by smell."

The Sense of Sight.— The eyes of insects are of two kinds, simple and compound. Of the simple eyes there are generally three, situated in a triangle on the front of the head. These eyes have but a single lens, and, it is supposed, they are used to observe very near objects. The

[1] *Anosia plexippus.* [2] *Cyanitris pseudargiolus.* [3] *Pieris oleracea.*

compound eyes, situated on the sides of the head, are composed of numerous simple eyes, which are complex in structure. The number of simple eyes in the compound eye varies in different insects. The ant has about fifty simple eyes in its compound eye. The compound eye of the dragon-fly (Fig. 26) contains

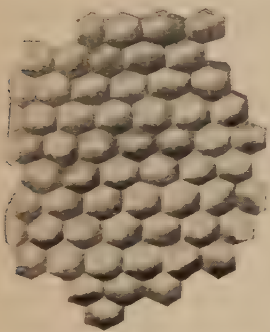


FIG. 25. Fragment of outer surface (cornea) of eye of dragon-fly, much enlarged, showing the hexagonal facets. Drawn from nature by Miss M. E. Wise.

FIG. 26. Head of dragon-fly. Enlarged, to show well-developed compound eyes forming sides and upper part of head. From a photograph.

20,000 simple eyes. In the compound eye, the outer surface or cornea of each simple eye is hexagonal. These hexagonal surfaces are joined together, forming a many-faceted cornea for the compound eye (Fig. 27). These eyes composing the compound eye see independently of each other. Each one is able to see but a small part of any object before the compound eye, so that insects see images and objects not as entire things, but in mosaic; that is, the object viewed seems to the insect to be composed of many small independent parts.

Some insects do not have eyes. Those insects which live constantly in the dark, such as those which are

exclusively under the bark of trees, as a certain beetle;[1] or parasitic in the skin of certain animals, as the spider-like fly;[2] or live in dark caves, as the small ground beetle;[3] or lead subterranean lives, as the small beetle[4] which dwells in ants' nests.

FIG. 27. Section through eye of fly (*Musca vomitoria*), showing arrangement of nerve-endings of simple eyes beneath cornea (*c*). (After Hickson.)

FIG. 28. One of the simple eyes (*ommatidium*) from the compound eye of the fly (*Musca vomitoria*). *c*, cornea; *pc*, pseudocone; *pg'*, pigments surrounding and separating each eye from the other; *R*, central axis of the nerve-ending semidiagrammatic. (After Hickson.)

At certain stages in growth and development some insects find no use for eyes. The larvæ of flies, commonly called maggots, being placed by their parents upon proper food, into which they frequently burrow, need no eyes. The same is true of Hymenopterous larvæ, the offspring of bees and wasps. The larvæ of beetles with like habits are also eyeless. But all these forms when they pass from this stage to the adult form possess eyes.

[1] *Ptilium.* [2] *Nycteribia.* [3] *Anophthalmus.* [4] *Claviger.*

Many larval forms, such as caterpillars and others which move about in quest of food, possess simple eyes in varied numbers.

Just how well and how accurately insects can see, is still an open question. It is evident that insects can perceive objects in motion better than at rest. Anyone who has ever disturbed a bumblebee's home, or a hornet's nest, knows that, though in a comparatively safe place, a movement on his part is likely to lead to his discovery and bring down the wrath of some scouting bee. It is probable, then, that the principal use of the compound eye is to perceive, not the form, but the movement of objects. It is further believed that insects cannot clearly perceive objects at a distance greater than six feet away, and that with few exceptions, such as the dragon-fly and honey-bee, insects are guided rather by the sense of smell than that of sight.

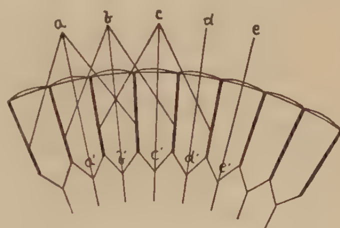


FIG. 29. Illustrating mode of vision in a many-faceted eye. (After Lubbock.) The light enters through cornea. The rays which strike the sides of each tube or cone are absorbed by the black pigment which surrounds each tube. Accordingly, those rays of light only which pass through the crystalline cones directly (or are reflected from their sides), such as *a–a′*, *b–b′*, *c–c′*, *d–d′*, *e–e′*, will ever affect the nerves at *a′*, *b′*, *c′*, *d′*, *e′*. According to Lubbock, the larger and more convex the eye, the wider will be the field of vision; while the smaller and more numerous are the facets, the more distinct will be the vision.

The Sense of Hearing.— The location of the auditory organ in the grasshopper (Fig. 203, *E, aud.*) is on the side of the insect immediately back of the thorax. The oystershell-shaped covering is simply a highly attenuated and fully stretched portion of the body cover-

Fig. 30. Front leg of cricket, showing ear-like organ (*a*).

ing. This cover corresponds in its use to the tympanum of our own ear. On the internal surface of this tympanum there are two horn-like processes, and attached to these is a very delicate little sac filled with a transparent fluid. This sac represents the membranous labyrinth, and is connected with the auditory nerve, which goes to the brain. This tympanal structure is to be found in the common black cricket, familiar katydid, and their allies, on the inside of the tibia of the front leg. The organs of hearing have different locations in different insects. It has been demonstrated that the antennæ of the male mosquito vibrate to the sound-wave of the tuning-fork. It is quite probable that a number of other insects perceive sounds through nerves which terminate exteriorly in the antennæ. The functions of the antennal nerves of insects are varied, capable of perceiving contact, odor, and

Fig. 31. Wing-covers of male katydid. The one on left shows heavy file-like structure on under side near base (enlarged just above wing); the one on right shows membranous structure near base with pointed ridge on upper side (enlarged just above wing), extending outward. The right wing is passed under the left wing, the sharp ridge rasps upon the file of the left wing, the membrane of the left wing vibrates, producing the "song" of the katydid.

sound. The antennæ may be considered, then, to have within them three classes of nerves: nerves of touch, of smell, and of hearing.

Production of Sound.— Insects have no true voice. We are all familiar with the shrill cry of the cicada or harvest-fly, the song of the katydid, and the chirp of the cricket. These are no doubt calls to other individuals of the same species. The cicada produces its piercing notes from a pair of membranes on the under side of the base of the abdomen of the male. The membranes cover depressions and vibrate rapidly somewhat like two kettle-drums. It is only the male that possesses these organs. This has led some one to say in rhyme:

> "Happy the cicadas' lives,
> For all have voiceless wives."

The student, with the male cicada in hand, will not have to wait long before he is permitted to hear and observe these sound-producing membranes in action. The katydid brings forth its song by rubbing its fore wings upon each other. (Fig. 31.) The male cricket will not usually remain long under a glass tumbler before he begins rubbing the base of his upper wings on the base of his under wings (Fig. 32), producing that familiar clicking sound. Certain moths and but-

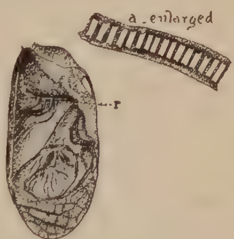


FIG. 32. Wing-cover of male cricket, showing sound-producing apparatus. Each wing-cover is equipped with one of these files, *r*, enlarged at *a*, and a scraper. When the cricket wishes to call, he elevates his wings so that the scraper of each wing rasps on the file of the other, when the wings are moved sidewise. This sets the membranous wing-covers in vibration and produces the characteristic chirp of the cricket.

terflies make crackling noises by rubbing their palpi against the base of their long probosces. The buzz of the honey-bee is caused by the vibration of the wings. In Japan a number of insects, notably among them a night cricket, are prized for the peculiar noises which they make. They are looked upon there as we regard canaries, and are kept in cages and cared for simply for the pleasure derived from hearing their characteristic sounds.

CHAPTER III

PROTECTIVE DEVICES

". . . . . Then marked he, too,
How lizard fed on ant, and snake on him,
And kite on both; and how the fish-hawk robbed
The fish-tiger of that which it had seized;
The shrike chasing the bulbul, which did hunt
The jeweled butterflies; till everywhere
Each slew a slayer and in turn was slain,
Life living upon death. So the fair show
Veiled on vast, savage, grim conspiracy
Of mutual murder, from the worm to man,
Who himself kills his fellow."—*Arnold.*

In this life, among us and about us, animals and plants as well as men bring to their aid every means which will in any way secure advantages to themselves and their posterity. Man has many cunning devices; ferocious wild animals have strength and prowess; yet both of these show due respect for the defensive weapons of the bee and the wasp. Bees have stings, beetles have guns. More successful in escaping the many predatory enemies of insects, however, are those that by imitation or simulation succeed in appearing not what they are but what they seem.

Means of protection are evident in every stage of insect life: the egg, the larva, the pupa and the adult frequently possess marked tendencies for shielding themselves from harm by reason of some peculiar trait or characteristic.

The Egg's Defense.— In the case of the egg, too frequently members of its own generation are its worst

enemies. The lacewinged fly[1] finds her offspring fond of their unhatched brethren; so the mother insect pro-

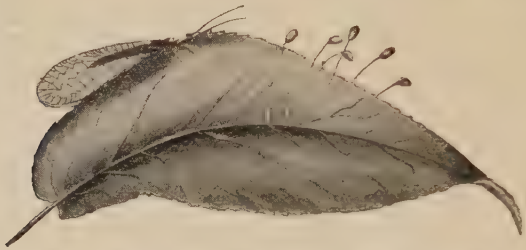


FIG. 33. Lace-winged fly and eggs, showing means of protection used by mother in placing eggs on stiff stalks of hard silk about one-half inch high.

vides a defense for her young still in the helpless stage by placing each egg upon a pedicel (Fig 33). Now as each egg hatches, the young one drops down upon the

FIG. 34. Ventral view of insect (*Orthezia graminis*) without egg-mass attached.

FIG. 35. Dorsal view same insect with long fluted covering over egg-mass attached to body. A protection for the eggs.

leaf or supporting surface beneath, and his brothers still remain high out of reach of this young bit of active life with an appetite to satisfy.

[1]*Chrysopa* sp.

FIG. 37. Larva of caddis-fly in case of sticks constructed by itself as protection against its enemies. When disturbed, it draws itself up within the house of sticks, mud and pebbles.

FIG. 36. Elder cane, showing top view of holes drilled by tree-cricket, a protective receptacle for her eggs. At left, part of cane split to show eggs in position.

FIG. 38. Larva of interrogation butterfly (*Grapta interrogationis*) about to pupate, showing protective many-barbed spines. From a photograph. Enlarged.

The Larvæ resort to many means to escape enemies. Some emit noxious juices, some "play 'possum," some assume an attitude of fierceness, and others simulate objects not subject to attack.

The Pupa frequently secures protection by assuming on the pupa-case colors closely resembling the support, or by taking the form of some object associated with it.

FIG. 39. Pupa of interrogation butterfly, showing protective knots or processes at exposed points liable to contact with other bodies. From a photograph. Enlarged.

FIG. 40. Dorsal view of the pupa of black swallowtail butterfly on white saucer, showing protective resemblance. Photographed from life.

The nascent pupa-skin in some insects appears to have the capacity to assume within certain limits the colors of its support. (See Figs. 40, 42, 42*b*.)

The Adult.— Did you ever observe a moderate-sized black or bluish beetle running away from under a stone or board you may have overturned? Have you

FIG. 41. Pupa of interrogation butterfly on upper part of under side of branch, protected by its resemblance to a fragment of leaf below it. After photograph by V. L. Kellogg.

ever collected such, and while handling it heard now and then a peculiar popping sound? These are the bombardier beetles. (See Fig. 43.) You will soon learn to know them by their bluish, blackish, or greenish bodies, with head, prothorax and legs yellowish or reddish yellow. These beetles have at the hind end of the body little sacs in which they secrete a volatile fluid; so, when one of these bombardier beetles is about to be overtaken by a pursuing enemy, a sudden pop, and he surprises his would-be captor with a report not unlike that of a little popgun, and then bewilders him with a load of smoky gas fired into his face. During this momentary bewilderment of his adversary, the bombardier beetle makes good his escape.

FIG. 42. Two pupa-cases of black swallowtail butterfly. The one on left has attached itself to white stick, the one on right to black stick, showing adaptation of color of pupa-case to its surroundings. About three-fourths natural size. Photographed from life.

There are but few of us who have not at some time experienced the sting of a bee or a wasp. Among bees this weapon is brought into use, not alone as protection against intruders, such as man, but is much used against the unwelcome visitors of its own tribe. Had not nature equipped the bee with such means of defense, this valuable insect, on account of the attraction the honey presents to man and other animals, would years ago have succumbed to the attacks of those seeking its precious stores.

The formic acid and the other toxic elements probably present in the fluid ejected from the glands of the body of the attacking bee, while discomfiting to us, are quite deadly to the bees. This poisonous fluid can be secreted from the blood-cells of the bees, but when it is injected

FIG. 42*b*. Pupa-case of black swallowtail butterfly on white saucer, side view, showing protective resemblance in coloration of the pupa-case to the white saucer. Natural size. Photographed from life.

FIG. 43. The bombardier beetle (*Brachynus americanus*). Enlarged three times.

FIG. 44. The "stink-bug" (*Podisus spinosus*). Rendered distasteful to birds by its ability to give off an offensive odor. Enlarged about two and one-half times.

into the tissues, by means of another's sting, death follows. When the honey-bee stings the human flesh the sting generally remains, and the bee, if not killed before, dies on account of the wound caused by the tearing away of the organs connected with the sting. This sting, then, is not so much for the protection of the individual as for the defense of the home and its

FIG. 45. "Bags" of the bag-worm moth larva, made of closely woven web covered by bits of sticks. The larva weaves the "bag" as it travels, for protection. The male emerges as a moth. The female spends her life as a grub-like form in her "bag."

sacred treasures; true patriots, these bees. Not so with the wasps and hornets: they sting repeatedly without endangering their own lives.

"The sting is composed of two spears of a polished, chestnut-colored horny substance, which, supported by the sheath, make a very sharp weapon. In the act of stinging, the spears emerge from the sheath, about two-thirds of their length. Between them and on each side of them is a small groove, through which the liquid, coming from the poison-sack, is ejected into the wound.

"Each spear of the sting has about nine barbs, which

are turned back like those of a fishhook, and prevent the sting from being easily withdrawn. When the insect is prepared to sting, one of these spears, having a little longer point than the other, first darts into the flesh, and being fixed by its foremost barb, the other strikes in also, and they alternately penetrate deeper

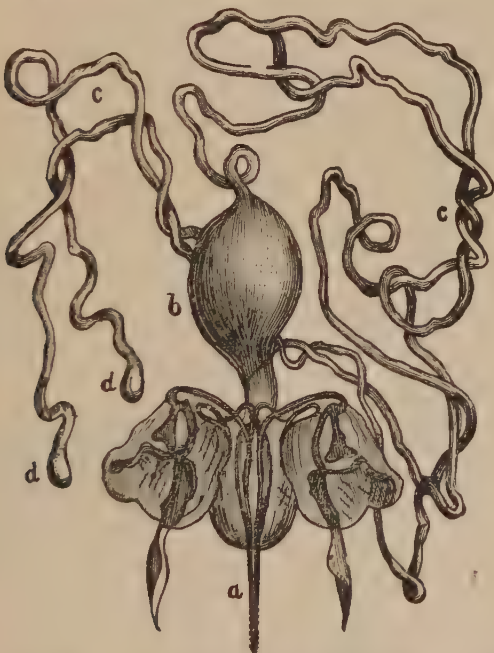


FIG. 46. The sting of the worker bee, and its appendages. (Enlarged, from Girard.) *a*, sting; *b*, poison sac; *c c*, poison glands; *d d*, secreting bags.

and deeper, till they acquire a firm hold of the flesh with their barbed hooks. Meanwhile, the poison is forced to the end of the spears, by much the same process which carries the venom from the tooth of a viper when it bites." (GIRARD.)

The muscles, though invisible to the eye, are yet strong enough to force the sting, to the depth of one-twelfth of an inch, through the thick skin of a man's hand.

FIG. 47. A walking-stick, protected by its resemblance to its surroundings.

FIG. 48. Leaf butterfly (*Kallima paralecta*) on left, showing protective resemblance to leaf on right. (After Wallace.)

Sympathetic Coloration.— So far we have spoken only of active means brought into use by insects in protecting themselves. Did you ever notice that the grasshoppers which live along the roadway and those living

almost exclusively upon the sandy and dusty ground, are dust-colored, while other grasshoppers, that live in the grass exclusively, are of a greenish color? Not only are they greenish in color, but in the case of a certain green grasshopper which spends much of its time upon the lamb's-quarter, there are marks of red corresponding to the red markings upon the green lamb's-quarter, showing further resemblance to surroundings. These colors have not been assumed as a matter of choice by the insects, just as we choose the colors of the clothing we wear, but have arisen through slow and gradual development. Is it not evident that the green grasshoppers upon the dusty road would be very conspicuous objects for birds and other enemies? If perchance a few should be somewhat gray or dusty in color they would be more likely to escape the notice of enemies, and naturally would tend to reproduce others of like color. Thus the matter of color not only becomes firmly fixed but most decidedly pronounced. And the same might be said about the dust-colored insects among the green grass.

"The world is made up," says Scudder, "of eaters and eaten, of devices to catch and devices to avoid being caught." So, whenever we find very large numbers of one species of insect life prevalent we will do well to look about to see if we can ascertain what trait of character or propitious conditions have furnished this group sufficient protection to enable the individuals to increase in such numbers.

Mimicry.— A feature of greatest interest among adult insects, and, we may say, one of the most successful in its purpose, is that means of defense which is secured

through what we are wont to call mimicry. The definition of this term, a word not in all respects expressing the intended meaning, can probably be best given in illustrations.

We are all familiar with that old-fashioned brown butterfly to be seen lazily making its way over the meadows in the late summer days; and sometimes in the

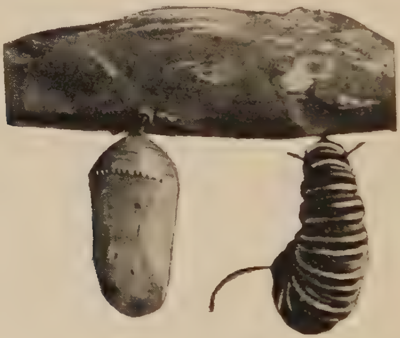


Fig. 49. Caterpillar about to pupate, and chrysalis of the monarch butterfly. Photographed from life.

autumn great strings of them may be seen moving southward, or clusters of them hanging to the branches of a tree in such numbers as to obscure the color of the leaves. This is the monarch or milkweed butterfly,[1] to be found wherever the milkweed grows.

From its careful, easy manner of flight in exposed places, this milkweed butterfly evidently takes little thought of predatory birds, and the reason is that insectivorous birds care nothing for it. If perchance a bird, a young inexperienced fledgling, pounces upon one of these milkweed butterflies, it soon lets go, be-

[1] *Anosia plexippus.*

Fig. 50. Mimicking and mimicked forms. Forms with W are wasps, with protective gs. All the others are moths resembling wasps. Photographed by V. L. Kellogg.

cause when the beak presses the insect's body, therefrom is emitted a rank carroty odor extremely distasteful to the bird. Possibly every young bird has this lesson to learn at least once — that is, that this brown, black-marked butterfly is not a dainty tidbit. And may we not say that this lesson after repeated learnings by successive generations becomes instinctive, and the insect immune from the attack of the birds?

All this is of great importance in determining the

welfare and existence of this species of butterfly. Other butterflies have not the power to emit this noxious odor and distasteful fluid as a means of protection; but some of them have succeeded by slow and gradual changes in assuming colors closely resembling those of the more favored species.

Most remarkable among these is the simulation of the viceroy butterfly.[1] On account of its relation to the milkweed butterfly it has been fitly termed the viceroy, and the milkweed butterfly has been called the monarch. As will be seen from the illustrations (Figs. 48 *a*, *b*), the general appearance of the two is much the same. The viceroy, however, is smaller, and bears a transverse black band upon the hind wing. This butterfly was once much darker than it is now. The brown color was present in a small degree, and this coloring has increased by natural selection until we have the present protective form. Has this change of color been carried on through the conscious activity of the insect? In other words, "Can the Ethiopian change his skin, or the leopard his spots?" Mimicry is not consciously carried on, but has to be accounted for by natural selection; that is, those viceroys having the greater amount of brown were more likely to deceive the birds than those with less,—consequently they lived to reproduce in kind others with prominent brown markings, and among them those displaying the brown most prominently were most likely to live to reproduce again in turn, the brown colors increasing, and so through a long series

[1] *Basilarchia archippus.*

of generations until we have the present form. Thus natural selection slowly, yet potently, shapes the destiny not only of insects, but of all animals and plants.

MIMICKED FORMS. Insects with powers of defense. From photographs.

FIG. 51.
The honey-bee.
(*Apis mellifica.*)

FIG. 52.
A wasp.
(*Vespa occidentalis.*)

FIG. 53.
A bumblebee.
(*Bombus Howardi.*)

MIMICKING FORMS. Insects without powers of defense; protected by their resemblance to dreaded insects. From photographs.

FIG. 51*a*.
A fly.
(*Eristalis latifrons.*)

FIG. 52*a*.
A beetle.
(*Clytus marginicollis.*)

FIG. 53*a*.
A fly.
(*Volucella evecta.*)

CHAPTER IV

SOLITARY LIFE

Some insects lead a social life; other insects are solitary in their habits. We find within the insect tribe many hermits, with almost miraculous foresight, expending their lives and energies constructing abodes for the protection of their young as well as storehouses for food to nourish their young. Unattended, the young grow from infancy to maturity within these little darkened homes, prepared and provisioned by a parent who in most cases has gone before the offspring mature.

The solitary wasps are the most interesting forms of this class. These insects are of two sexes. It is the duty of the female to make a nest for each one of her young, and to see that nourishment is furnished it sufficient for its sustenance until maturity. The males are irresponsible creatures, assuming little if any direction in family affairs. The adult wasp lives upon fruit or nectar; the young are reared upon animal food. Each species is particular as to the kind of food selected, so that we find certain species always provisioning their nests with flies, others with spiders, others with caterpillars, and yet others with grasshoppers, and so on. Generation after generation and year after year the same species are reared upon the very same class of food, procured in like manner by the parent guided by the force we are wont to call instinct.

Social Development.—In the development of social life among insects we find all gradations,—the solitary, the gregarious, and the social. The independent insects, such as the chinch-bug, take little thought for their offspring. Then come forms such as the solitary wasps, to be treated further on; these provide for their young. Then come the mining-bees, which live apparently in communities in sandbanks, but which in reality have but an entrance or hall in common, off from which each insect has a separate apartment where no other intrudes. Then come the ants and bees with their communistic life, division of labor and sharing of responsibilities. In such an organization is to be found the most advantageous plan of life. The ant alone is helpless, but in its organization, the colony, it is one of the most successful, because, by reason of numbers and division of labor, it secures protection, food, shelter, and insures like conditions for its offspring. The most successful are the most sociable.

Mud-daubers.— Familiar to all of us are the mud-daubers. They are to be seen any bright day flying around the moist earth in the vicinity of our wells, or nervously walking about on the muddy edges of some little pool or pond. If you will watch one of them you will soon observe it kneading and rolling up the clay with its mandibles into pellets to build a strange little cell for its young in the most peculiar and out-of-the-way place. You may at some time have found one of their domiciles attached to an unused garment in your cloak-room; you have doubtless seen these

Fig. 54. A mud-dauber (*Pelopœus cementarius*). ×1½.

mud-daubers' homes pasted to the under side of your porches, around the barns, and not infrequently under the bridges of the highway. If you will break open one of these nests you will find, if the time is right, the developing form surrounded by spiders in a comatose condition; or if perchance the regular occupant is gone you will find the remnants of these same spiders in this little adobe structure.

The strength and prowess frequently displayed by these solitary wasps in securing their prey is often remarkable. They will frequently enter dark hay-mows and old garrets in quest of spiders for their young. The writer on one occasion observed one of these attempt to drag a good-sized ground-spider up the side of a church to a knot-hole in the weather-boards, where the wasp was constructing a nest. Laboriously and yet steadily did it go diagonally up the building, moving backward with its mandibles fastened in its load, until it reached an elevation of about three feet, when, its strength giving out, the wasp, spider and all fell to the ground. This operation was repeated three times before darkness interfered with the insect's work for that day.

When these female wasps are ready to deposit their

FIG. 55. Mud-daubers and their nests. From photograph. × ⅔.

eggs they prepare a nest, as it were, by digging a hole in the ground or excavating a cavity in some tree or partially decayed log or stem, or constructing a cell of mud or of wood pulp. Here they place the eggs singly, and proceed to capture the characteristic food for their young. These caterpillars, or whatever the prey may be, they sting in such a way as to stupefy. In this condition the captives remain, to become food for the young upon their appearance.

The actions of the parent in capturing this prey and placing it in a position in the nest as food awaiting the hatching of the egg, are among the most interesting observations to be made in the study of animal life. A number of remarkable instances have been recorded. One which will serve the purpose here, and which goes even farther in showing the use of tools among insects, was observed by Dr. S. W. Williston, of the University of Kansas, and is here given in his own language:

"Even the casual observer, to whom all insects are bugs, cannot help but be struck by the great diversity and number of the fossorial Hymenoptera of the plains. Water is often inaccessible, trees there are few or none, and only in places is the vegetation at all abundant. A much larger proportion of insects, hence, find it necessary to live or breed in holes in the ground, than is the case in more favored localities. Especially is this the case with the Hymenoptera, great numbers and many species of which thus breed in excavations made by themselves.

"While packing specimens on an open space, uncovered by buffalo-grass, in the extreme western part of Kansas, the early part of last July, the attention of a friend and myself was attracted by the numerous wasps that were constantly alighting upon the ground. The hard, smooth, baked surface showed no indications of disturbance, and it was not till we had attentively watched the insects that we learned what they were doing. The wasp is a very slender one, more than an inch in length, with a slender, pedicellate abdomen; it is known to entomologists as *Ammophila Yarrowi* Cres. They were so numerous that one was distracted

FIG. 56. The wasp, *Ammophila*, stinging a caterpillar. (After Peckham.) ×4.

by their very multiplicity, but, singling out different individuals, we were enabled to verify each detail of their operations. An insect, alighting, ran about on the smooth, hard surface till it had found a suitable spot to begin its excavation, which was made about a quarter of an inch in diameter, nearly vertical, and

FIG. 57. The tarantula-hawk (*Pepsis formosa*), one of the giant wasps, which stores its burrows with tarantulas. From a photograph.

carried to a depth of about four inches, as was shown by opening a number of them. The earth, as removed, was formed into a rounded pellet and carefully carried to the neighboring grass and dropped. For the first half of an inch or so the hole was made of a slightly greater diameter. When the excavation had been carried to the required depth, the wasp, after a survey of the premises, flying away, soon returned with a large pebble in its mandibles, which it carefully deposited within the opening; then, standing over the entrance upon her four posterior feet, she (I say she, for it was evident that they were all females) rapidly and most amusingly scraped the dust with her two front feet, 'hand over hand,' back beneath her, till she had filled

the hole above the stone to the top. The operation so far was remarkable enough, but the next procedure was more so. When she had heaped up the dirt to her satisfaction, she again flew away and immediately returned with a smaller pebble, perhaps an eighth of an inch in diameter, and then standing more nearly erect, with the front feet folded beneath her, she pressed down the dust all over and about the opening, smoothing off the surface, and accompanying the action with a peculiar rasping sound. After all this was done,—and she spent several minutes each time in thus stamping the earth, so that only a keen eye could detect any abrasion of the surface,—she laid aside the little pebble and flew away to be gone some minutes. Soon, however, she comes back with a heavy flight, scarcely able to sustain the soft green larva, as long as herself, that she brings. The larva is laid upon the ground, a little to one side, when, going to the spot where she had industriously labored, by a few rapid strokes she throws out the dust and withdraws the stone cover, laying it aside. Next, the larva is dragged down the hole, where the wasp remains for a few minutes, afterwards returning and closing up the entrance precisely as before. This, we thought, was the end, and supposed that the wasp would now be off about her other affairs,—but not so; soon she returns with another larva, precisely like the first, and the whole operation is again repeated. And not only the second time, but again and again, till four or five of the larvæ have been stored up for the sustainment of her future offspring. Once, while a wasp had gone down the hole with a larva, my friend quietly removed the stone door that she had placed near the

FIG. 58. The wasp, *Ammophila*, using a stone in packing the dirt over its burrow. (After Peckham.) × 4.

entrance. Returning, she looked about for her door, but not finding it, apparently mistrusted the honesty of a neighbor, which had just descended, leaving her own door temptingly near. She purloined this pebble and was making off with it, when the rightful owner appeared and gave chase, compelling her to relinquish it.

"The things that struck us as most remarkable were the unerring judgment in the selection of a pebble of precisely the right size to fit the entrance, and the use of the small pebble in smoothing down and packing the soil over the opening, together with the instinct that taught them to remove every evidence that the earth had been disturbed."

Coinciding with this are the interesting observations subsequently made by George W. and Elizabeth Peckham: "Just here must be told the story of one little wasp whose individuality stands out in our minds more distinctly than that of any of the others. We remember her as the most fastidious and perfect little worker of the whole season, so nice was she in her adaptation of means to ends, so busy and contented in her labor of love, and so pretty in her pride over her completed work. In filling up her nest she put her head down into it and bit away the loose earth from the sides, letting it fall to the bottom of the burrow, and then, after a quantity had accumulated, jammed it down with her head. Earth was then brought from the outside and pressed in, and then more was bitten from the sides. When, at last, the filling was level with the ground, she brought a quantity of fine grains of dirt to the spot, and picking up a small pebble in her mandibles, used it as a hammer in pounding them down with rapid strokes,

thus making this spot as hard and firm as the surrounding surface. (Fig. 58.) Before we could recover from our astonishment at this performance, she had dropped her stone and was bringing more earth. We then threw ourselves down on the ground that not a motion might be lost, and in a moment we saw her pick up the pebble and again pound the earth into place with it, hammering now here and now there until all was level. Once more the whole process was repeated, and then the little creature, all unconscious of the commotion that she had aroused in our minds,—unconscious indeed, of our very existence, and intent only on doing her work and doing it well,—gave one final, comprehensive glance around, and flew away."

CHAPTER V

SOCIAL LIFE

For where 's the state beneath the firmament,
That doth excel the bees for government?
—*Du Bartas.*

So work the honey-bees,
Creatures that by a rule in Nature teach
The act of order to a peopled kingdom.
—*Shakespeare.*

WITHIN reach of almost every school-house in the land there exists a colony of bees. Every school-boy and school-girl knows the honey-bee, and many of them have become familiar by experience with some of its traits. The busy bee has method in its business, and its mode of life is worthy of our careful study.

The Colony.—A colony, hive or household, consists of from twenty-five thousand to thirty-five thousand worker bees, a few hundred drones, and a queen. The greatest number of bees are present in the hive during the honey-gathering season, when their services are most needed, and the least number of bees will be found in the hive during the winter months, when the fewer the mouths there are to feed, the longer will last the food. It frequently happens that during the honey season the number exceeds thirty-five thousand, and in the

winter the hive may dwindle far below twenty-five thousand and still retain its organization.

In every hive there is a form of government, political you may call it, but uniform throughout the whole realm of the bee world. The same offices exist in all and the functions of each office are constant.

The Queen.— The most important personage in the beehive is the queen, whom people, before her true function was known, called the "king bee," on account of her size. From neither of these terms must it be

FIG. 59. A queen bee. × 2.

inferred that she is in any sense a despot, for, though the most important and attractive personage in the hive, she is more frequently ruled than ruler. She receives, however, every attention that can be bestowed upon her by her attendants; and well may they caress her, for around her centers the existence of the hive.

The queen is the only fully developed female in the hive. She is the mother of the entire colony; she lays all the eggs, from which hatches every bee that exists within the hive. The eggs which she lays bring forth workers, queens and drones in accordance with the well-

organized plans of this government. The eggs which produce queens and workers are in nowise different. They are spoken of as fertile eggs; that is, they contain within them the male element. The eggs which are unfertilized bring forth drones. There is no evidence, however, that drones cannot also be produced from fertilized eggs.

The eggs hatch in about three days after being laid. The newly hatched larvæ are fed by nurse bees with a lactic fluid which is secreted in a portion of the alimentary canal of the nurse bee. All are fed with this until about three days old, when the bees intended to become workers and drones are given a substance familiarly known as bee-bread. Those larvæ which are to make queens are fed throughout their whole growing period with this lactic fluid from the nurse bees; a substance which, on account of its being the sole nourishment of the queen not only during her period of development but likewise throughout her whole existence, is commonly called "royal jelly." From this it will be seen that the only difference between the queen and the worker is in the quality of the food given to them in their growing stages.

The presence of a queen is necessary to the existence of every colony, and should the queen be removed from any cause the workers at once set about to develop another queen by continuously feeding a newly hatched larva with this royal jelly. The queen spends about three days in the egg stage, six in the larval, and seven in the quiescent or pupal stage, before appearing as an adult.

The queen cells are houses in which the queens are

reared, and are different from those in which the worker and drone bees are reared. Figure 60 shows the large queen cells extending out from the comb, not unlike a peanut in shape. These, it might be added, are cells which have been constructed in an artificial way; that is, when the bees are forced to produce a queen out of the regular swarming season. At the regular season of

FIG. 60. Brood comb, showing queen cells protruding.

the year, when the bees give regular attention to rearing a few queens, the queen cells will be found usually at the ends and bottom of the comb.

These young queens will become fertile and begin laying eggs when they are ten to twelve days old. An active queen will deposit from two to three thousand eggs daily. She is of great service to her colony for two years, and may live still longer. The queen is intensely jealous, and will brook no rival in her domain. The appearance of another queen is a signal for a battle, which generally terminates in the death of one. It is on such occasions only that queens use their stings.

Should a newly hatched queen discover another queen cell, if not prevented by the worker bees she will immediately tear open and kill the young queen found therein.

The Drone.— The drone is developed from the unfertilized eggs, placed in cells somewhat larger than worker

Fig. 61. A drone bee. ×2.

cells. These develop in about twenty-four days, remaining three in the egg, six in the larval, and fifteen in the pupal stage. These are reared in large numbers during the swarming season, in order that the fertility of all queens may be assured. The drone, as is generally known, is the male, and has no tools for collecting honey or gathering pollen, and is therefore, after the swarming season, looked upon as a useless member of society, only to be stung out of the hive. This the worker bees hasten to do as soon as his period of usefulness is past.

The Worker.— The worker is the bee familiar to all of us; the one respected for its business air as well as its powers of defense. Workers mature in about twenty-one days, spent in the following stages: three days in the egg state, five in the larval state, and thirteen

Fig. 62. A worker bee. × 2.

in the pupal stage. The worker, as its name implies, is the laborer of the hive. It gathers all the honey, the pollen, the propolis or bee-glue, carries water, secretes wax, builds comb, prepares food, nurses the young brood, defends the hive, and cleans house. The workers are busy night and day.

In a well-regulated colony the division of labor is as follows: The first work the young bee performs after it is two or three days old is to prepare food and feed the larvæ in the cells; its next duty, when ten or twelve days old, is to secrete wax and build the comb; at about twenty days old it becomes a honey-gatherer from the field. The young bee is easily known by the pale color and lack of strength; in a few days it becomes stronger and is well covered with hair; the aged worker is known by its tattered wings and bald body. The average life of the worker is about five weeks. If you will sit somewhere between the hive and the bee pastures you will frequently see the old bald bees falling by the wayside; their strength is exhausted and their wings are no longer fit for duty.

Fig. 63. Secretion of wax scales. (Enlarged, from "Illustrirte Bienen-Zeitung.")

Bees, like people, have dispositions; they have moods. These dispositions seem to be transmitted

FIG. 64. Head and mouth-parts of worker bee. *Eye*, compound eye; *ant*, antennæ; *lb*, labium; *md*, mandible; *g*, maxilla; *lp*, labial palpi; *pg*, paraglossa; *f*, tongue or glossa.

from generation to generation, so that certain bees have to-day the reputation of being kind, gentle and tractable, and others irritable, easily disturbed, and ever ready for a fray. They are characterized as industrious and frugal. They are not, however, at all times possessed of integrity, for if the nectar from the flowers becomes scarce they are wont to look about for some weak neighboring colony to rob of its small and feebly defended store of sweets.

Have you ever seated yourself by the side of a colony and watched the comings and goings of the bees? Have you seen the pollen baskets, well laden, being taken into the hive? Have you ever seen the young ones go forth to establish themselves in housekeeping? These are some things which you must see in order to appreciate them; so arrange with some beekeeper in your neighborhood for a visit to his apiary. He, I am sure, will be only too glad to act as your instructor during your visit.

When there examine the honeycomb proper, and the brood comb, containing workers, drones, and queens. Make a drawing of the shape of the mouths of each one of these cells. Is the shape of these mathematically accurate; that is, is each of them a true hexagon?

Swarming. — The young bees are hatched in such numbers in the spring that the old hive cannot longer accommodate all of them. This, together with the mortal jeal-

Fig. 65. A newly settled swarm. Photographed from life. (Courtesy of the Century Co.)

ousy of the queens, makes the establishment of a new home necessary. On some bright spring morning, therefore, in every well-established colony there arises a great commotion, attended by unusual buzzing sounds. The bees begin to pour forth in an impetuous current. The crowd of merry hummers, circling, fill the air with an indescribable rustling murmur. More keep crowding through the doorway, until the air is darkened by a large and giddy circle of bees. In a little while the center grows darker, and this in the vicinity of some branch upon which all pour down in the same fashion that they left the hive. Somewhere within this living mass is the queen of the hive. Here they "settle" to await, we have reason to believe, the return of the couriers sent to spy out the land. Good reports being received, they are up and away to the place sought out. The would-be emigrants, evidently aware of the contingencies of such a journey, make full preparations by filling their honey-sacs before leaving the old hive. This amount of food will by economy furnish a week's subsistence.

This is "swarming," and you will readily see that this procedure is in the interests of the race; for if all lived in one household, however large it might be

FIG. 66. Hiving a swarm. Photographed from life.

and however numerous its occupants, should that house meet destruction nothing would be left to tell the tale or replace the loss. But with the distribution of homes throughout the land, the likelihood of a common catastrophe is much lessened if not wholly improbable.

Ants.—"If the statesman or the philosopher would study a perfect communistic society, let him throw away his histories of poor human attempts and go and study thoroughly the nearest ant-hill. There he will find no love for friend or wife or child, but a love for every one. There everything is done for the good of the whole, and nothing for the individual. The state makes wars, provides food for all, cares for the children, owns all the property. He will find no complaint against the existing condition of society, no rebels; but the fate of each one is determined by the accident

of birth, and each takes up its work without a murmur. He will find that this perfect commune has developed courage, patriotism, loyalty, and never-failing industry; but he will find also that war, pillage, slavery, and an utter disregard of the rights of other communities and individuals, are as prevalent as they are among our own nations, where selfish private ambition has held sway so long." (COMSTOCK.)

Similar to the economy of the beehive, the workers are the most active and interesting forms within the colony. Like the worker bees, the worker ants are undeveloped females, and, as their name implies, they do all the work. This consists of building and defending the nests, caring for the young, and collecting food. They not only defend the hives, but they likewise carry on wars of conquest, frequently going forth to capture slaves. Some species of ants make a business of raiding the nests of other ants and bringing away the larvæ and pupæ to their own nests, to be reared and kept as slaves. So far has this gone in the case of some species that the slaveholders have been dependent upon their slaves so long that they are unable to carry on the work without the aid of slaves, and become helpless when the slaves are removed. It would seem, too, that these slaves have been slaves so long that they have become such by instinct. Huber placed several of the slaveholders by themselves, where nearly all of them helplessly starved though plenty of food was accessible. A slave was then introduced. This slave immediately set to work constructing a nest and administering nourishment to those still alive, thus saving its stupid masters from death.

Ants also show their ingenuity in caring for herds. This system of stock-raising and dairying can be observed by any sharp-eyed student. The herds of the ants, or, as they are sometimes called, the ant cows, are the plant-lice or aphids,— such forms as molest your pansies. These it is that are cared for by the ants. In

FIG. 67. "Mud shed" built by ants for sheltering their "herds" of aphids. Photographed from life by M. V. Slingerland.

some cases they show great forethought in taking the eggs of these aphids into their homes and caring for them, rearing the aphids and carrying them out and placing them in green pastures. The aphids reward the ants for this attention by giving them a sweet substance generally called honeydew. This substance appears in minute drops upon the back of the aphid. It is frequently excreted in quantities sufficient to coat the leaves

of branches below the aphids. Sometimes this fluid is noticeable on the stone walks above which there are trees in which are plant-lice. This method of ants conducting their farming system the student can observe for himself. Whenever ants are found going up and down a tree, it may be taken for granted that they are going and returning from aphid pastures. The redbud tree is a favorite with some species of aphids. A branch of this upon which aphids and ants are found can be removed and the stem placed in a vessel containing water. The leaves will remain green for some time and the relations existing between aphid and ant can be observed.

If the student has not already discovered it, his attention is now called to the fact that there are three classes of ants in a colony: males, females, and workers. The first two are winged and the workers are wingless. During the summer it will be possible for the student to observe a number of ants coming forth from the hives and taking flight. Many of the colonies of ants are doing this at the same time. It is during this flight that the female, commonly called the queen, is fertilized. She drops to the earth, tears off her wings, these being no longer required, and endeavors to secure a place to deposit her eggs. She is sometimes taken into a colony of her own species, and sometimes she starts a new colony from the eggs which she lays. Comstock has shown in a series of interesting experiments that it is possible for a queen of the carpenter ant[1] to build her cell, lay her eggs and bring forth the first of her brood without taking any food whatever. The cell she builds

[1] *Camponotus pennsylvanicus.*

is a closed one, and contains no store of food excepting what may be within the body of the queen. The term queen, as in the case of bees, is a misnomer, since these queens do not rule but are simply the mothers of their respective colonies. The queen ant differs from the queen bee in that she is not jealous, and a number of queen ants may be found living peaceably within the same hive.

The ant-eggs are small and not easily observed. The larvæ are white and legless. Those oblong egg-shaped bodies which are frequently mistaken for eggs are the pupa-cases or cocoons from which the adults, with the tender assistance of their nurses, will emerge.

Wasps.—Wasps, in their habits, are of two classes,—social and solitary. Of the former, the hornets[1] and yellow-jackets[2] are the best known. The hornets build large spherical homes from the weather-beaten wood fibers which they have scraped off, chewed up into a pulpy mass, and then plastered out into thin layers with their deft mandibles. Boys and girls who have been brought up in wooded countries are familiar with the appearance of the large spherical hornets' nest depending from some tree or bush. In the fall of the year these deserted nests are sometimes gathered and placed in the stables to repel, as farmers believe, all manner of diseases from the horses kept there. The sting of these wasps, called into use upon the slightest provocation, is much to be respected. Though these insects are somewhat warlike, when approached quietly and cautiously one may have the privilege of standing

[1] *Vespa* sp. [2] *Polistes* sp.

close by and watching the workers come with their little pellets of wood-pulp and spread the material skillfully and frugally over the place desired.

The yellow-jackets build nests of the same material, but construct them of only a single layer of cells. They

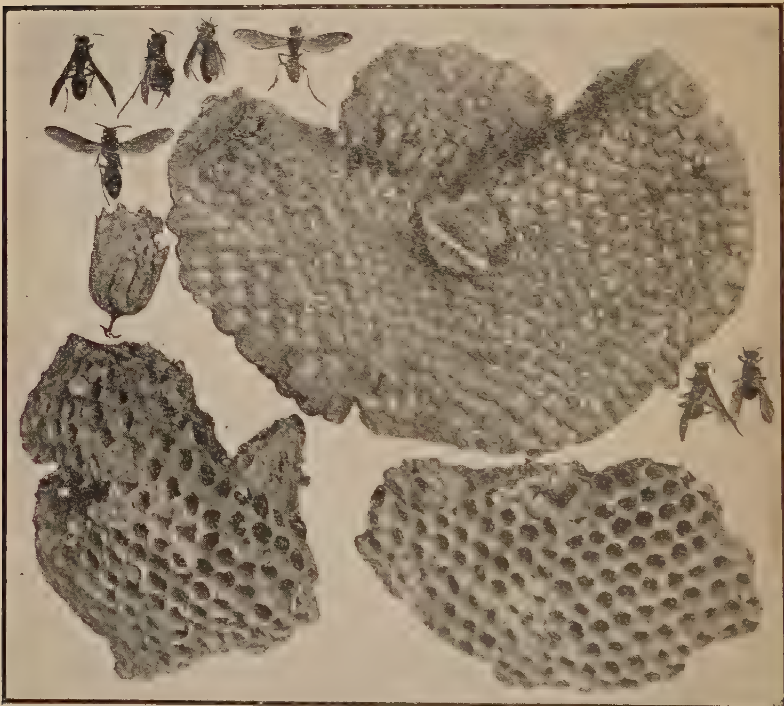


FIG. 68. Yellow-jackets (*polistes* sp.) and their nests. From a photograph. ⅓.

locate them generally in some sheltered place, such as under a large flattened rock which lies loosely upon other rocks near the ground, or under a porch or similarly sheltered place.

The life history of these two kinds of wasps is much

the same. In the fall of the year the fertilized queens hibernate in the crevices and sheltered nooks. In the spring they look about for suitable nesting-places; with wood-pulp gathered by themselves they build up the first layer of cells. The queen deposits an egg in each of these cells and feeds the newly hatched grubs a week or ten days until they pupate. Ten days later the perfect wasps have come out of these cells and are ready to take up their share of the responsibility in the work of the colony. These first wasps are workers. The work of gathering the wood-pulp and moulding the same into cells now devolves wholly upon these workers. The queen devotes her time and attention to depositing an egg in each of the cells. The colony consists of the queen and an increasing number of workers, until the late summer, when drones are developed. As

FIG. 69. Hornets' nest. Drawn from nature by Miss M. E. Wise. ½

the cool weather announces the approach of winter, the workers and queens desert the hive, leaving the helpless drones and unattended young to perish. The workers wander about until killed by frost. The queens alone seek some sheltered place to spend the winter.[1]

FIG. 70. Hornets' nest; one side removed, to show arrangement of combs within. Drawn from nature by Miss M. E. Wise.

The social wasps are predaceous. They feed their young upon insects which they have masticated. Adults seek also the nectar of flowers, the juices of fruits, and the honeydew of plant-lice.

The queens, drones and workers are similar in color. The queens are larger than the workers. The drones do not sting, but unfortunately their close resemblance to the hostile and much-dreaded workers leads us to repel the advances of all alike. The number of individuals existing at one time among these social wasps is often quite great, but there are not so many species as there are among solitary wasps.

[1] In Brazil there are perennial communities of wasps founded by swarm after the fashion of bee colonies. (Von Ihering.)

CHAPTER VI

INSTINCT

The remarkable actions of the wasps related in the foregoing chapter naturally give rise to the question, What prompts and directs such actions? Activities of this class are common to all, or nearly all, of each species possessing such traits. Each works after its own manner and in a way that is uniform for each species. Some of these acts occur before the insect is old enough to be taught. Such acts are said to be instinctive. Instinctive acts are for the most part, if not altogether, performed without reflection. Insects do certain things in a certain way. Their actions seem to accord with their natural surroundings, but should their environments be changed their actions are not changed accordingly. For instance, a certain wasp provisions its nest with a large grasshopper. The wasp drags the grasshopper along by one of the antennæ. When the antennæ are cut off, the wasp looks around the head, and finding no antennæ, gives up the task and flies away. It never occurs to the wasp to take hold of a leg and proceed. An excellent example is the case of the trap-door spider, not itself an insect, but one of the insect allies. This trap-door spider makes its home in tubular burrows beneath the surface of the ground. It covers its tube with a hinged trap-door. When the spider is pursued it seeks refuge within its home, closing the trap-door after it. Where these spiders dwell the ground

is carpeted with moss, so in making this trap-door the spider covers it with moss,— an act for protection, for when the door is closed no trace of the spider's hiding-place is visible. If in the absence of the spider the moss be removed from the door and the earth bared over considerable space around the door, the spider will upon her return carry moss across the open space and re-cover her trap-door, making this not a protection but the most conspicuous object on the situation. That which prompts the wasp to drag the grasshopper only by the antennæ, and which causes the spider to cover its trap-door with moss, is termed instinct. Had the wasp and the spider shown their ability to cope with changed conditions, their actions would have been due to reason. These instinctive actions are those which are performed without learning or practice.

Actions of the Newly Born.— Instinct is, then, best illustrated by the actions of the newly born forms. Young wasps, just out of the pupa-case, though limp and almost helpless, when disturbed protrude the sting and move the abdomen about in various directions, in their endeavor to sting the disturber. They seem to perform these acts as perfectly as do the mature wasps. Stinging, then, is a purely instinctive act. The young caterpillar's first act (p. 14) after leaving the egg is to turn around and eat the egg-shell. All the young caterpillars of the swallowtail butterfly do this. Not one of them before doing this has had an opportunity to be taught this act. They do it instinctively. The origin of instinct is an open question: some authorities believe that the act of one individual repeated many times becomes a habit, and that this habit can be transmitted

from generation to generation until it becomes an instinct; that is, instincts are "inherited habits." Other authorities believe that instinct is due to natural selection. Insects with certain habits favorable to their existence live to reproduce in kind, while those without these characteristics perish before they have brought forth young. For instance, according to this view, the earlier generations of wasps did not all sting. Those that did not sting were more liable to succumb when attacked, while those who used their stings vigorously survived, and lived to beget forms with a tendency to sting. In time the stinging wasps were the only ones left, and among them the most violent stingers would still be the most liable to perpetuate the species.

Acts of Mature Life.—Among the best examples of instinctive acts of mature life, stand the interesting habits of insects. The making of homes, the homing instinct, as already noted, in the case of bees and wasps (pp. 79, 80), the waging of wars and the making of slaves among ants (pp. 81, 82), are examples of this class of instincts. It must be conceded that every individual is not likely to perform these acts in identically the same manner, and further, that there is a possibility of action somewhat intelligent while in the performance of these instinctive acts of mature life. It is not at all likely that every Ammophila (p. 68) makes use of a pebble in the work of storing food for the sustenance of offspring. To those that do this, intelligent action must be accredited. Such insects have profited by the experiences of their own lives.

Acts Associated with Reproduction.— The construction of homes and the storage of food for their young are the

highest forms of insect instinct in this class. Such instinctive acts have been fully discussed in the previous chapter. To the same class of acts belongs the care with which certain insects, such as butterflies, deposit their eggs in the vicinity of the natural food plant of their offspring. The most wonderful of all is that of the Pronuba moth, discussed elsewhere (p. 112). The

FIG. 71. Female wasp (*Sphex speciosus*) carrying a cicada to her burrow, an instinctive act associated with reproduction. Natural size. (After Riley.)

Pronuba moth gathers the pollen and carries it to the proper place in order that the yucca blossom may be fertilized to furnish succulent seeds for the young which is to hatch from the egg she places in the ovary of the yucca flower. This is an instinct most wonderful in its perfection, and certainly as obscure in its origin.

Limitations of Instinct.— Instinct has certain bounds, and when activities have passed beyond these bounds they become something more than instinct. A wasp

that was unable to drag away the grasshopper because it could not find antennæ to take hold of, and the spider that made its subterranean home conspicuous by covering it with moss, are examples of the limitation of instinct. The activity of certain insects seems to go beyond the bounds of instinct and enter the realm of thought. Such insects are credited with intelligence.

Instinct and Reason.— A colony of bees finding a dead snail within their hive, endeavored to drag it out. This was an instinctive act, since it was instinctive with them to repel all intruders, but when they were unable to remove the snail they at once covered it over with wax and hermetically sealed it in its position. This was no longer an act of instinct, but an act of reason. It is evident here that the nerve centers acted independently of any past experience; that is, there was reason shown and intelligent action manifested.

The following may be considered the chief instinctive acts: Choice of food, partaking of food, capture of prey, building of homes or nests, storing provisions either for themselves or their offspring, spinning cocoons of a definite form. When a customary mode of performing these instinctive acts is changed, the change is likely to be due to intelligent adaptation to new modes of life. Insects which for many generations have built their nests in a certain kind of places, such as under rocks, forsake these places and choose better adapted places under the eaves of houses. Of all the intelligent acts the one given elsewhere (p. 68) stands among the first; that is the case of Ammophila using a stone to pound the earth over her nest.

CHAPTER VII

THE MUTUAL RELATIONS OF PLANTS AND INSECTS

"Insects have been inhabitants of land plants since their origin in early Paleozoic ages, and the mutual relations of plants and insects have ever been intimate."—*Cope.*

Plants and insects illustrate interdependences. Insects rely upon plants for nourishment; plants depend upon insects for proper maturation of seed. Some insects are injurious to certain forms of plant life. Such feed upon the foliage, or live within the body of the plant. Some insects seek their food within the nectaries of flowering plants, and in so doing advance the welfare of the plant. To this latter class we will confine our study.

Near the close of the eighteenth century Sprengel first pointed out the useful purposes of colors, scents and singular forms of flowers. He brought forth the facts that nectar-producing plants have the nectar so situated as to be protected from rain, yet easily accessible to insects. He concluded "that the nectar of these flowers is secreted for the sake of insects, and is protected from rain in order that the insects may get it pure and unspoiled." His first observations, then, were that plants exist for the benefit of insects. Later, however, he made additional discoveries, which led him to believe that many flowers are absolutely incapable of being fertilized without the aid of insects, and therefore the secretion of nectar and its protection from rain by the plant,

and the bright color of the corolla, are contrivances made by the flower in its own interests; that is, to accomplish the fertilization of the flower. Such flowers are, he says, fertilized by some one species of insect or by several species, and the insects in approaching the nectar brush pollen from the anthers with various hairy parts of their bodies and convey it to the stigma. Sprengel did not, however, perceive the advantages the plant gains, further than the mere formation of the seed. Knight and Herbert, two later workers, perceived, in a degree, the effects of this fertilization of plants by insects upon subsequent plant generations.

It remained for Darwin to place the almost forgotten work of Sprengel upon a broad basis. "No organic being fertilizes itself for a perpetuity of generations, but that a cross with another individual is occasionally, perhaps at long intervals, indispensable." Darwin further showed that, in higher forms and the greater number of lower animals, the sexes are separate; that those forms having the function of the two sexes present in the one animal, even these pair regularly. Breeders of animals and cultivators of plants have found that continued in-and-in breeding deteriorates the stock, while crossing with another breed or another strain of the same breed increases the strength and productiveness of the offspring.

Since continuous close-fertilization is detrimental to the interests of the plants, Nature has brought about contrivances to prevent such recurrence. She does this in two ways: (1) by modifications in the structure of the flower so that the pollen cannot possibly fall upon the stigma of its own pistil; (2) in other plants, whose

pollen does fall upon its own stigma, by rendering this sterile to its own ovule but fertile when transferred to the flower of another variety of the same stock. Briefly and in a general way, this sums up the advance of our knowledge upon this interesting subject. Many subsequent investigations have elaborated these principles by the detailed study of various forms of flowering plants.

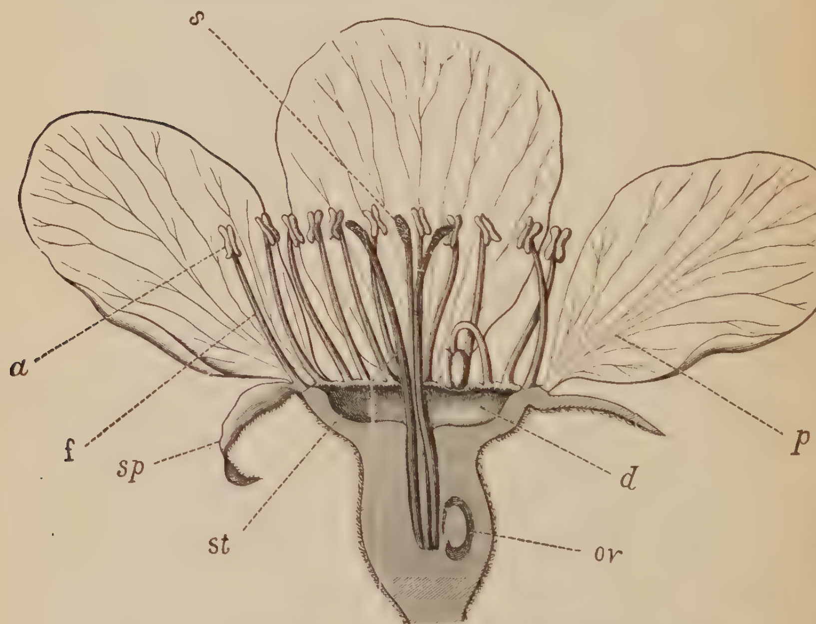


Fig. 72. Enlarged section of a Bartlett pear flower: *st*, style; *sp*, sepal; *f*, filament; *a*, anther; *s*, stigma; *p*, petal; *d*, disk; *ov*, ovule. (After Waite.)

Plants whose Flowers are Sterile to their Own Pollen but Fertile to Pollen Brought from Other Plants of Same Species. More than fifty species of plants have been found to be partially or wholly sterile to their own pollen, but fertile to pollen transferred from other plants of the same

kind. The apple and pear belong to this group. According to Waite, cross-fertilization is an important factor in the production of pome fruits.

The pear blossom is a typical flower, composed of five brownish-green calyx lobes, five white or pinkish petals, numerous stamens, a five-celled ovary, and five styles and stigmas. The pear forms at the base of the blossom. There is within the blossom a yellowish-green saucer-shaped disk, upon which the nectar is secreted. Extending from this disk to the ovary are five styles. Within the ovary are the ovules, which upon proper fertilization become seeds. The ends and a strip down one

FIG. 73. Buds of Bartlett pear. (After Waite.)

side of the green styles are rough, caused by fringe-like projections for facilitating the reception and retention of the pollen grains. The stamens terminate in small roundish bodies, termed anthers. The four-celled anthers, when mature, split, allowing the pollen to escape

in two masses as though the anthers were two-celled. This pollen as well as the nectar serves to attract bees and other insects. The bright showy petals proclaim to the insects the location of the nectar.

FIG. 74. Cluster of Bartlett pear blossoms—natural size. From a photograph. (After Waite.)

When a bee visits the flowers the rough stigma brushes from the insect's hairy coat some of the pollen which adhered to it while seeking nectar in other trees, and if these trees were another variety this blossom is then cross-pollinated. The pistils mature (that is, become ripe, to receive the pollen) two or three days before the

pollen escapes from the anthers of the same flower. The stigma often extends through the petals before they are fully open, thus offering the possibility of pollination from some earlier blossoming variety, — another way for cross-fertilization to occur.


FIG. 75. Flower of Bartlett pear—natural size. (After Waite.)

The process of fecundation Waite describes: "Soon after its protrusion the stigma secretes a sugary fluid, often in sufficient quantity to be quite perceptible. In this the pollen grain readily germinates and throws out a slender, thread-like tube, which grows downward into the pistil and through specially soft tissue, adapted to its growth, until it reaches the ovules. Here it enters an opening in the two outer coats of the ovule and comes in contact with the germ-cell, or egg-cell. A number of interesting and complicated changes now take place in the protoplasm of this cell and in the end of the pollen tube. A part of the contents of the latter actually passes through the cell-walls into the egg-cell, which, under this stimulus, immediately begins to grow and divide, ultimately developing into the germ of the seed. This stim-


FIG. 76. Bud of the Bartlett pear, with the petals removed, showing the incurved stamens—natural size.


FIG. 77. Bud of the Bartlett pear, showing only the five pistils—natural size.

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ulus not only causes the seed to grow, but also the surrounding fruit, the latter depending upon seed development in most cases. In some cases, however, the growth of the pollen tube may help to

FIG. 78. Bartlett pear cross-pollinated with the pollen of the Easter pear.

stimulate the fruit to develop independently of the fecundation of the ovule, which may or may not afterwards result, and this probably accounts for the fact that many little fruits begin to develop, but afterwards drop off."

Waite has conducted experiments in the cross-fertilization of pears and apples for several years, by placing sacks over the buds to prevent the introduction of foreign pollen, by removing the stamens before ripe and polli-

FIG. 79. Seeds from crossed and from self-pollinated Bartlett pears: *a*, from crossed pears; *b*, from self-pollinated pears. (After Waite.)

FIG. 80. Self-pollinated Bartlett pear.

nating the pistils with pollen from other varieties. The actions of insects towards the blossoms were also noted. His conclusions in part are: Some of the common varieties of pears require cross-fertilization; some varieties are capable of self-fertilization; pollen is transported from tree to tree by bees and other insects and not by the wind; bad weather keeps away insect visitors and hence materially affects the fruit yield; self-fecundated pears are deficient in seeds, and

FIG. 81. Baldwin apple cross-pollinated with pollen of the Bellflower apple. (After Waite.)

FIG. 82. Large specimen of self-pollinated Baldwin apple.

FIG. 83. Small specimen of self-pollinated Baldwin apple. (After Waite.)

the seeds produced are usually abortive. The crosses are well supplied with sound seeds; the typical fruit and in most cases the finest specimens are from crosses. Accordingly, to secure the best results not only should an ample number of bees be placed in

FIG. 84. Section of an apple blossom. (After Waite.)

the orchard to insure the visitation of the blossoms, but the different varieties of each fruit should be placed promiscuously throughout the orchard in order to facilitate the work of cross-fertilization.

Plants whose Flowers are so Constructed as to Prevent Self-fertilization.—A papilionaceous flower is an example of a blossom so constructed as to prevent the falling of the pollen upon the stigma of its own pistil. The alfalfa blossom is an example of this class. Its structure and component parts are illustrated in Figure 85. It will be seen that the stigma of the ovary is higher than the pollen-producing anthers, so that the grains of pollen may all drop to the base of the flower and the ovule go unfertilized; such being the case, no seed would be formed. Small forms resembling seed might be found within the ovary at maturity, but these, not being fertilized, would not germinate.

From the shape and size of the alfalfa blossom, it is not probable that cross-fertilization could be safely accomplished by means of currents of air.

It becomes evident, then, that outside agencies must be called upon, and the plant must provide for these agencies. The agents in this case we find to be insects, and the reward offered by the plant for favors rendered is a sweet drop of nectar; that is, the flower in an enticing way places a tempting sip of nectar in such a position that when the insect has favored the flower with a few grains of pollen unconsciously brought from an adjoining flower and just as unconsciously left, the coveted sip may be enjoyed. It is evident, however, that the first flower visited will not be cross-fertilized.

The location of the coveted nectar at the base of

the flower, the action of the tongue of the bee and the work of the hairs under the head and upon the breast in placing the pollen upon the stigma, are shown in Figure 86 and also in Figure 85, *b4*. The flower gives material aid, by causing the stamens and pistils to spring up and strike the insect.

FIG. 85. *a*, cluster of alfalfa with bee feeding. *b*, bee thrusting proboscis into flower: *1*, vexillum; *2*, alæ; *3*, carina; *4*, reproductive organs (gametangia); *5*, calyx. *c*, alfalfa bloom with vexillum torn off: *2*, alæ; *3*, carina; *4*, reproductive organs (gametangia); *5*, stigma; *6*, anthers; *7*, calyx. *d*: *1*, filament; *2*, anther; *3*, style; *4*, stigma. *e*, pistil: *1*, ovary; *2*, style; *3*, stigma; *4*, ovules. *g*, highly magnified pollen grains.

A part of Müller's observations upon this point are: If in a young flower we cut through the claw of the carina, the column springs upward to some extent, carry-

ing with it the carina and alæ. If in another unexploded flower we carefully cut through one of the digitiform processes of the alæ, the parts remain motionless; but on cutting the processes of the other side, explosion at once follows. The pouched processes of the carina (Fig. 85, *b3* and *c3*) are thus sufficient to hold the column down without the aid of the processes of the alæ (*c2*); the alæ alone are not sufficient to hold the column down when the carina has been cut. Explosion can therefore be effected equally well by separating the anterior pouches, by separating the digitiform processes, or, finally, by depressing the alæ and carina.

FIG. 86. Pollination of alfalfa flower by bee. See fig. 64 for honey-collecting tools of bee.

If an insect inserts its proboscis in the middle line between the anterior pouches and the digitiform processes, or if it stands upon the alæ and thrusts its head in the middle line under the vexillum, in either case explosion follows. The stigma (*c5*) projects beyond the anthers, and therefore is the first to strike the under surface of the bee's body or proboscis; an instant later the anthers come in contact, dusting it with fresh pollen. The first flower that the insect visits is, of course, not cross-fertilized, but as the bee withdraws from the flower, self-fertilization inevitably occurs. Self-fertilization is undoubtedly efficient, for Hildebrand has shown that flowers which wither unexploded when insects are excluded produce seed by self-fertilization. The same au-

thor finds two imperfections in the mechanism. One is the possibility of the insect securing the nectar without exploding the flower; the other is that the flower continues to secrete honey after it has been fertilized.

FIG. 87. The many-flowered umbels of the milkweed. Photographed by W. C. Stevens.

A large number of representative matured pods were gathered from an alfalfa field less than one-half mile away from a large apiary, and a like number from another field of much the same soil, and practically under like conditions as the first field, except that the second field was situated twenty-five miles away from a colony of bees. No bees were observed in the field, and the character of the surroundings, there being no timber or probable living-places, was such as to preclude the possibility of wild bees in the vicinity. The pods from each locality were carefully opened and the number of seeds in each counted. In the field near the apiary the average number of seeds in a pod was found to be 5.58; seeds plump; pods numerous in cluster; pods having several spirals. In the other field the average number of seeds in a pod was 3.35; seeds in at least one-third of the pods were small and shriveled; pods few in cluster; short, with but few spirals. The seed crop of the first field, on this basis, could be estimated at two-thirds greater that that of the second field.

Plants with Special Adaptations for Bringing About Cross-fertilization.—The milkweed family[1] illustrates one of the many wonderful designs brought about by plants to insure cross-fertilization. The milkweed blossom is to be considered one of our highly specialized forms, and the high degree of development is due in a great measure to

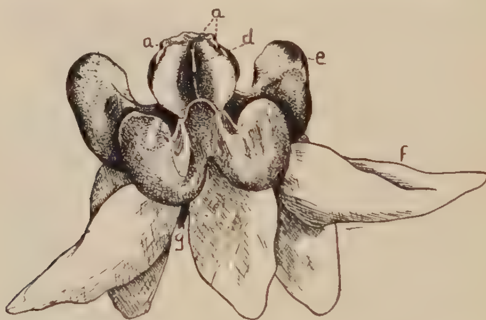


FIG. 88. Entire flower of the milkweed (*Asclepiodora viridis*). Enlarged. *a a*, location of corpusculum ; *d*, longitudinal slit which separates the anthers, and into which insect draws its leg ; *e*, cucullus ; *f*, petal ; *g*, sepal.

the actions of insects. The flower structure must be understood before the work of the insect can be appreciated. The blossom used to illustrate the arrangement of the parts is that of *Asclepiodora viridis*, or green milkweed. The five minute sepals (Fig. 88) are situated beneath and alternating with the five well-developed petals. By bending these downward as in the figure, the inner mechanism can be more easily observed.

Five hollow, fleshy, leaf-like organs immediately within, are attached to the central column. These are termed collectively cuculli, or singly cucullus. (Fig. 88.) This fleshy column is made by the union of the five staminal filaments, each bearing at its upper end an

[1]*Asclepiadaceæ.*

anther. The anthers lie close around the central stigma disk, each anther being separated from the other by a longitudinal slit (Fig. 88, *d*) formed by the margins of the anthers being extended

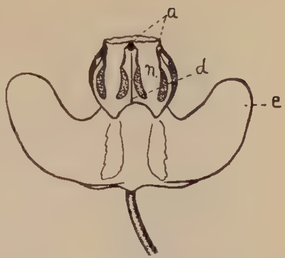


FIG. 89. Longitudinal section of milkweed. *a*, corpusculum; *d*, slit between anthers; *n*, pollen-mass (pollinium) in normal position within flower.

FIG. 90. Two pollen-masses (pollinia) joined by their bands (retinacula) to their central body (corpusculum). The fragment hanging down from the central body between these two pollen-masses is part of a leg of an insect which had been caught in the wedge-shaped slit in this body, and which had liberated itself by breaking off and leaving part of its leg fast therein. Greatly enlarged. Photographed by W. C. Stevens.

out perpendicularly as a slight triangular membranous expansion. Each anther bears two pollen-masses. Each of these masses is called a pollinium. Bands or retinacula unite each pollinium, to a dark central body, the corpusculum, situated at the top of the slit. The corpusculum is hard, horny, and upon examination is found to be grooved longitudinally. (Fig. 90.) This wedge-shaped groove lies in line with the slit between the anthers. The lower part of the slit between the anthers is wider, and leads up into the so-called stigmatic

FIG. 91. Honey-bee caught in entrapping slit of milkweed blossom. Photographed from nature by W. C. Stevens.

FIG. 93. Moth caught in several flowers of milkweed. One leg has been broken off in its struggle to free itself. Photographed from nature by W. C. Stevens.

FIG. 92. Cabbage butterfly held fast in milkweed blossom. Photographed from nature by W. C. Stevens.

FIG. 94. Honey-bee caught in several blossoms of milkweed. Photographed from nature by W. C. Stevens.

chamber. The cuculli secrete abundance of nectar, and of a quality which makes insects seek madly after it. The cuculli and the fleshy column are smooth, even slippery, the corolla yielding, so that insects in quest of this nectar find difficulty in retaining a firm footing. All the while the insect is clawing the disk and cuculli, never feeling stable, yet acquiring some of the much-coveted sweets. While insects are thus at work, their claws, or the hairs of the tarsi or the tibia, are caught in the wedge-shaped slit of the corpusculum. If the insect is strong enough, it brings away with it the corpusculum and its two swollen masses, one from each adjoining anther, or it breaks off the ensnared leg in its endeavors to escape. If the insect is too weak to pull out the pollinia or to sever its connection by breaking the retaining member, it must in consequence die. Such tragedies are not of infrequent occurrence. In case the insect has power to carry away the pollinia, its trouble and dangers are not over, for it will most likely visit another milkweed blossom, where the complementary contrivance awaits it.

This slit between the anthers is wider at the bottom for a purpose, and that purpose is to capture the pollinium which the insect has brought from another flower; so the insect, in slipping about again upon this second flower, finds itself fast when the pollinium has entered at the base of the slit. To facilitate this the more, these pollinia when first removed become, upon the drying of the bands or retinacula, twisted inward. This twisting inward of the pollinia enables their entrance to the slit to be made the more readily. When the pollinia

have entered the slit, the insect pulls them up into the stigmatic chamber. They will go no farther, and the insect finds itself a prisoner again. If escape is made it is generally by breaking the retinaculum. The insect then carries away the corpusculum and part of the

FIG. 95. Leg of insect with small chain of corpuscula. Photographed from nature by W. C. Stevens.

FIG. 96. Pollen-masses attached to leg of bee. *a*, central body (corpusculum); *b*, band (or retinaculum) joining pollen-mass to central body; *c*, pollen-mass (pollinium). Drawn from nature.

retinaculum. This serves to catch other corpuscula resting in their natural positions, so that we can frequently find insects that have continued their visits, bearing a whole chain of these corpuscula attached to a claw or some part of the leg. (Fig. 95.) Many insects are attracted by the nectar. It is evident that only the strong favor the plant. The honey-bee is among the most frequent visitors, and no student can remain long among milkweeds in blossom without observing successful cross-pollination or being an eye-witness to a tragedy.

The Yucca Lily and the Pronuba Moth.—The fertilization of the yucca blossom by a small white moth surpasses all other modes of cross-fertilization by insects, since the insect is not induced to do the work by tempt-

ing nectar, but pollinates the plant apparently with as much intelligence as a human being would do it. Not for any benefit the moth itself may derive therefrom, but that succulent seeds may be formed within the pod upon which its young may be nourished.

The yucca, or yucca lily as it is sometimes called, is a familiar plant. Its white flower may be characterized briefly by the rather short, distinctly spreading stamens, with the more extended pistil. The anthers are so remote from the stigma that self-fertilization can take place only by the merest chance.

The Pronuba moth is a showy white lepidopteron about one-half inch long, and seems to have been constructed especially for a purpose in the life of the yucca. The mouth of our common moths and butterflies consists of the two long maxillæ united to form a proboscis, used in reaching the deep-seated nectar of flowers such as the honeysuckle. On each side of the proboscis, near the base, is a mere protruding point, representing what is left of the once well-developed maxillary palpi; then there are two well-developed labial palpi curving up from beneath the head on each side of the proboscis, between which the proboscis is coiled up when not in use.

The female Pronuba moth, the yucca pollenizer, has all of these, but the little protruding point on each side of the proboscis is well developed into a four-jointed palpus. From its base there arises a highly specialized organ, which for want of a better name we call the maxillary tentacle. These tentacles are coiled somewhat similar to the proboscis, but are readily distinguished

from them by their large size, darker color, and spinous covering; also by their position, since the proboscis is situated between them.

The female Pronuba moth rests quietly during the day, head downward in the blossom of the yucca. About sunset, or soon after dark, she may be seen running up to the top of one of the stamens, and collecting pollen from the anthers by extending the tentacles and proboscis out over the stamens, giving her a firmer hold upon the stamen and bringing the head close to the anthers. She now moves her head back and forth, using the maxillary palpi to scrape the pollen from the anthers toward the tentacles. The pollen gathered, she packs it in a little pellet under her head, using her front feet as well as the tentacles. Then she goes to a second stamen, collects more in the same way, and then to another, until she has collected a pollen-mass larger than her head. (Fig. 97.) She generally flies to another flower to rest awhile, head downward. After resting, in some cases only a few minutes, in others a much longer

FIG. 97. Head of Pronuba moth, showing pollen-mass under head with maxillary tentacles coiled around it. Photographed from nature. × 6.

FIG. 98. Ovipositor of Pronuba moth for insertion of egg in deep ovary of yucca lily. (After Riley.)

time, she scurries around the base of the stamens, ascends between two of the stamens until her head is slightly beyond the anthers (Fig. 99), inserts her ovipositor (Fig. 98) into the ovary, there to place an egg.

FIG. 99. Female Pronuba moth ovipositing on ovary of yucca lily. Photographed by flashlight from life, in field, about 8:30 P. M.

She withdraws the ovipositor in about a minute. She retracts this interesting little tool by two or three jerky motions. She now quickly ascends the pistil and thrusts her uncoiled tentacles and proboscis into the stigmatic opening, rubbing them against the stigmatic surface. In doing this her head bobs up and down several times. She returns to the base of the flower, to ascend between

another pair of stamens and repeat the operation of egg-laying. In this way she places five or six eggs in the ovaries of this flower. After depositing each egg she ascends the pistil, and with the same motion, working

FIG. 100. Female Pronuba moth thrusting her tentacles and proboscis into the stigmatic opening, rubbing off pollen, thus bringing about fertilization of the lily. Photographed by flashlight from life, in the field, about 9:00 P. M.

her head vigorously (mostly up and down), places more pollen in the stigmatic tube. During all this time she is so intent upon the work that one can observe her closely with the aid of a lantern. The moths begin this work shortly after dark, and continue at work about an hour.

Now, why does this female Pronuba moth do all this? It has been shown that down in the stigmatic opening there is no nectar to attract her; she does not eat pollen. Then why does she perform this marvelous act of pollination? She does it to insure food for her young. For, though the eggs were laid in the ovary, unless the ovules were properly fertilized they would wither, would not develop; so the young caterpillars would perish. As it is, the hairy tentacles, surrounding and rubbing against the pollen-mass under her head, take off some of the grains of pollen, and these are left in the stigmatic chamber when she thrusts her proboscis and tentacles therein.

And what is the sequence of this act? The pollen in due time fertilizes the ovules; these begin to develop, and at this stage may be likened to newly formed garden peas in the pod. No one needs to be told that these young peas are more tender, more succulent than the fully mature pea. Just as these ovules are forming, the moth egg which is beside them hatches, and the little caterpillar finds awaiting him a breakfast of new peas. As the seeds develop, the larva grows; the two mature together. About the time the seed-pod is ready to burst open the larva bores its way out, descends the plant to the ground, burrows several inches below the surface, spins a silken cocoon intermixed with earth, there to spend the remainder of the summer, the fall and winter, awaiting the opening of the yucca flower the next summer, then to emerge to repeat the story,— a series of acts as yet unaccounted for.

Has the question occurred to you, what benefit is the plant to derive if the insect eats all the seed?

Were the total consumption of seed the rule, it is evident the plant would soon become extinct, and with it the Pronuba moth. Such is not the case; the elongate ovaries bear many ovules, more than the larvæ entertained will in all probability consume, and so enough seeds are left unharmed to insure the continuation of the yucca lily seeds, which will in turn arise to make possible the further existence of the interesting little Pronuba moths.

CHAPTER VIII

OUR FRIENDS AND FOES

NOT every one, indeed, is aware of the fact that insects fill an important part in the economy of nature. We receive direct benefits as well as material injuries from insects, and it is within the province of entomology to distinguish the character of the insects.

As scavengers, as fertilizers of vegetables and fruits, or as food for other animals, they not only concern man, but, philosophically considered, certain insects are seen to be essential to his very existence. From them we receive our sweetest of sweets, several inks and dyes, our finest of tapestries, a number of acids of chemical value, and laces and waxes of mercantile worth. That we receive injuries, no one needs to be told.

In nature the term "friend" is a relative one. From the standpoint of the tree-grower, the caterpillar of the handmaid moth, which deprives the young trees of their foliage, is an enemy. Dame Nature, however, is as much interested in the welfare of the caterpillar as she is in the advancement of the tree or even of its owner. The caterpillar has as much right to the tree as has the fruit-grower. A review of biologic time, however, shows that it was not Nature's intention that one form of life should predominate at the expense of another. Nature endeavors to maintain an equilibrium between plant and

animal life. Man, the predominant type, brings together large areas of the food plants of one insect, and here this insect finds conditions which favor its rapid multiplication. Its destructive possibilities become more apparent when directed against those forms of plant life from which man gains his sustenance; and in order to subsist, man is forced to turn his attention toward this plant-eating insect. Man has made this condition possible not only by planting large areas of one field crop or of fruit trees, but also by removing the native forests, the homes of the birds, man's friends. Not only has he destroyed the homes of the birds, but too frequently he has also ruthlessly taken their lives.

In discussing our friends and foes, let us subdivide them from the standpoint of the parties interested, and so consider them friends and foes of the fruit-grower, the farmer, the housekeeper, and finally of man himself.

OF THE FRUIT-GROWER.

The horticulturist is a student of biology, an observer of the workings of life. The life which the horticulturist studies is represented by that invisible stream of life within twig and leaf. If you would see the results of his studies, look first at the wild crab and then at the Winesap, the Gano, the Jonathan. Has he not studied this life-current well?

A successful fruit-grower must also be able to determine what insects are injurious and what are beneficial. To do this, then, he must know their life history, and by that is meant the time of year when the eggs are laid; where they are laid; when they hatch; whether they hatch out as caterpillars or in a form

FIG. 101. Scale insect (*Pulvinaria pruni*) on plum twigs. Subsists on the sap, which it draws out through its slender beak. An insect injurious to horticulture. From a photograph.

similar to the parent; what they feed upon and the time when they mature; how their food is procured,—whether by grasping and chewing with jaws, or by sucking through a beak. These things he can learn from books, but he can learn them far better, just as he has gained his best knowledge in horticulture, by the vigilant use of his eyes while following his chosen profession. If the insect eats the leaves, as caterpillars do, the successful horticulturist knows that this insect can be reached by poisonous sprays thrown upon the leaves. If the insect procures its food by inserting its beak into the leaf, the fruit-grower will readily understand that a poisonous spray will not kill this insect, since it does not eat the leaf spread with Paris green, but pushes its beak down through the poison into the leaf and withdraws its sustenance unharmed.

One of the earliest instances of successfully combatting an insect took place in Sweden. In the time of Linnæus the Swedish ship-builders were seriously bothered by a borer destroying the ship timbers in their yards. They applied to Linnæus for assistance. This noted naturalist, after giving the subject of the life history of the insect careful study, told the ship-builders that if they would submerge the timbers in the sea during the month of May they would have no further trouble from the pest. The naturalist had found that these borers were the larvæ or grubs of a beetle which lays eggs upon the wood only in the month of May. He readily perceived that if this wood could be placed where the beetles could not find it during this month they would be compelled to deposit their eggs elsewhere. Then when the eggs hatched, the young

would perish for want of proper nourishment. Let us see if we can apply similar principles to the work in hand.

Let us take up the insect enemies as we meet them in the year, and discuss them chiefly with a view to prevention rather than to combatting them after they have made their appearance.

Tent Caterpillar.— If the keen-eyed horticulturist will walk through his orchard during the winter months when the trees are bare, he will now and again perceive a twig that has a peculiar swelling, and he will see that the swelling is caused by a band of small eggs carefully laid side by side and well covered over by a waxy substance. These are the eggs of the apple tent caterpillar,[1] which are ready to hatch with the first days of spring. The almost microscopic caterpillars will go out, ready to feed upon the opening buds. Now if the horticulturist will apply his pruning-knife and remove the twigs and cast them into the fire, he will have coped very successfully with one of his insect enemies. If, on the contrary, however, he is spending his time in other pursuits at this winter season, there will appear early in the spring in his orchard great clusters of caterpillars well housed in large webs in the forks of his trees. They will go from this house

Fig. 102. Eggs of apple-tree tent caterpillar, surrounding an apple twig. Drawn from nature, by Miss M. E. Wise.

[1] *Clisiocampa americana.*

to defoliate his tree and to lessen the fruit crop thereon. If he desires to combat them at this time the labor is much increased: the whole fork must be cut out, or else the large web with its inhabitants must be brushed away. But before this stage has been reached the horticulturist has already suffered a loss in foliage destroyed,—a loss which he cannot repair. The trees, if neglected, are soon stripped of their foliage. The vital powers of his fruit trees, then, are so greatly taxed that they usually bear little or no fruit that season.

Canker Worm.[1]—As the horticulturist is at work among his trees about the time the foliage begins to cast a

FIG. 103. Parents of the spring canker worm: *a*, female; *b*, male (*Paleacrita vernata*). Drawn from nature, by Miss M. E. Wise.

shadow, he frequently notes small caterpillars dropping down by a thread from the disturbed branches of the trees. A few days later he sees the same trees nearly stripped of their leaves. If these caterpillars, swinging in the air by their silken threads, do not alarm him, he will soon be more emphatically impressed by the defoliated trees. If, however, he is familiar with the life his-

[1] *Paleacrita vernata* is the scientific name for spring canker worm. Another species, *Anisopteryx pometaria*, appears usually in the fall.

tory of this insect, he will know that the female is a wingless moth which comes out from her hibernating-case early in the spring and ascends the tree to lay her eggs thereon. If he has been aware of the probable presence of this female in his orchard, he will have banded his trees with ropes of hay or paper or cotton. These bands will have been smeared with printer's ink, coal tar or pine tar, or some such adhesive substance, which would have arrested her in her ascent and have held her fast until she perished. Or if he has not done this, the first caterpillar swinging from its thread will have been to him a signal for the advance of the spraying-pump.

The Codling Moth.[1] — Almost every lover of fruit has seen a wormy apple, and the well-informed know that the cause of that hole in the apple is a little worm, the parent of which we call the codling moth. This apple worm is one of the most serious obstacles in the way of the profitable production of apples by the average fruit-grower. From one-fourth to one-half of the apple crop in the United States is ruined annually by this insect. It may be well, then, to give this important pest grave attention. It is likely that it was introduced into the United States from Europe in packages of apples or pears, and was probably brought over about the middle of the 18th century. At the present time it is considered a pest in every section where apple trees are bearing. It is chiefly distributed by means of the apple, in which it lives until it is full-fed. In barrels in which these apples are packed it finds a very suitable place

[1] *Carpocapsa pomonella.*

for its transformations. From the pupa-case it awakens to spread depredation wherever fate may have placed it.

The loss due to this apple pest reaches enormous sums. One year it was estimated that the loss in the State of Illinois due to this apple worm amounted to $2,375,000, or one-half of the average apple crop. Another year the insect is said to have caused a loss of $2,000,000 to the apple crop of Nebraska.

The average annual crop of apples in New York

FIG. 104. Some codling moths — natural size. After photograph by M. V. Slingerland.

amounts to about 5,000,000 barrels: at $1.50 per barrel this would amount to $7,500,000. Although New York fruit-growers are fighting this insect with modern methods, it is estimated that the wormy apples amount to about one-third of the total crop; or in other words, New York apple-growers pay an annual tribute for the ravages of this pest of about $2,500,000 worth of apples. To this must be added at least $500,000 worth of pears. This makes a total tax which is to be borne by the fruit-growers of New York amounting to $3,000,000.

This insect's food consists largely of apples, wild

haws, crab apples, and quinces. It also shows a decided taste for pears, and has been found upon peaches, apricots, and cherries.

Comparatively few fruit-growers, doubtless, are acquainted with the parent moth. The insect is about an inch in wing expanse, and has brown-colored front wings with lighter brown-colored hind wings. It might

FIG. 105. A pear and two apples. The petals have fallen. The calyx lobes are still widely spread. Just the right time to spray. After photograph by M. V. Slingerland.

be well here to enter somewhat into the life history of the codling moth, in order that the stages through which this insect passes may be more fully understood. The egg is laid upon the side of the apple, like a minute drop of milk adhering to the skin of the fruit. It has frequently been supposed that it is always laid upon the fruit itself; this is not the case, as investigations

have shown that the eggs have been laid upon the twigs as well as upon the apple. In a few days, dependent upon the character of the weather, the egg hatches, and the young worm seeks its first meal. It wanders about upon the surface of the apple until it finds some angular place like the blossom end, or where a leaf of the tree touches the surface of the apple. Generally the worm crowds in between two of the calyx lobes, and gets its first meal within the little cavity at the blossom end. Note the fact that in the majority of cases this little worm gets its first meal in the blossom end of the apple. And here it spends several days feeding around in the calyx cavity before it mines to the center of the apple. These first few days of the apple worm's life, which are usually spent in feeding in the blossom end of the apple, have proven to be the most vulnerable phase in the life of the insect. It is during this time that it can be killed by the poisonous spray to be spoken of later.

You are all familiar with the appearance of the worm-hole in the apple and the bits of brown dust around the margins of the hole. When the caterpillar is ready to leave the fruit it pushes away this dust, and crawls out, leaving the open worm-hole; when one has a wormy apple in hand, it can be easily told by the absence or presence of these pellets of dust whether the worm is still within the apple or not. If the fruit has fallen to the ground, the caterpillar proceeds to crawl to some secure and suitable place in which to make preparations for becoming a moth. It seeks a suitable place to spin its cocoon, in which to undergo its further transformations. Some go to trunks, large

branches, or into the crotches of trees, to pupate under the rough, loose bark. Others seek quarters in near-by fences or piles of rubbish.

If the worms are carried in the apples into the store-room, or packed with the fruit when it is picked, they spin their cocoons, after leaving the fruit, in the crevices and angles of the barrels, or in any secure portion

FIG. 106. A pear and two apples. The calyx lobes are closing up, especially on right-hand apple. Almost too late to spray effectively. After photograph by M. V. Slingerland.

of the store-room. The first brood generally attains the adult stage about the first of July. This brood coming out at this time is ready to lay eggs which will in turn hatch and attack the apples still remaining upon the tree. The insect is two-brooded in the United States. The worms of this second brood enter the fruit not so frequently at the blossom end. They generally enter on the side, making a spot which greatly disfigures the fruit.

A word about the habits of the parent moth. It is

nocturnal in its habits. Unlike many other moths, the codling moth is not attracted to the light. This has been shown many times by experiments with lanterns. Nor is it attracted to baits of any kind. How then can this insect be overcome? Since the codling moth cannot be taken at lights or by traps, the only possible means of destroying it in the adult stage is by keeping the fruit cellars screened in the early spring, so that the emerging moths may be prevented from escaping until they are captured within the cellar and killed. No satisfactory way has presented itself for the destruction of the eggs. A few of the pupa-cases may be found and destroyed, but it appears that the chief and surest remedy lies in attacking the young apple worms.

Many experiments have shown that spraying is the most effective means of ridding the orchards of the pest.

First of all and by all means secure a first-class spraying-pump. Time and money used in working with a home-made device or cheap spraying-pump is worse than wasted. Get the best spraying-pump the market affords, and your work will be more than repaid. Having secured a pump, use a mixture of Paris green in accordance with the formula given on page 303.

The time to spray is a few days after the blossoms have fallen and before the calyx leaves have begun to close up. (Fig. 105.) The object of the spray is not to water the leaves nor the sides of the apple. The idea in the mind of the sprayer is to fill the little cup at the rose end of the young apple with this fluid. This can be done only while the calyx leaves are yet open. From this you will see that different varieties of apples will require to be sprayed at different times. If

you will review in your mind what has been said, you will see that when these cups at the blossom end have been filled with this poisonous fluid the water will evaporate and leave the particles of poison therein to be eaten by the young caterpillar at his first meal, and, consequently, at his last meal. This is the secret of combatting the codling moth successfully. If you rid your orchard of the first brood it will be evident that there will be no second brood. Having neglected this, however, the second brood can only be destroyed by shaking the tree and gathering and destroying the wormy apples.

The Honey-Bee. — The above are some of the more injurious insects met by the horticulturist. Now let us note his friends of this class. Not the least among these is the honey-bee, which visits his orchards, his vineyards, his strawberries, blackberries and raspberries, and brings about greater results than is generally credited. It was formerly supposed that plants fertilized themselves, but it has been more recently shown that many plants are so constructed as to prevent self-fertilization; or, in other words, plant life, like animal life, will "run out," as we term it, by in-and-in breeding. And nature has so constructed the plant itself that it is impossible in some cases for the pollen of its own anthers to fall upon the stigma of its own ovary. In other cases the stigma is sterile to the pollen from its own anthers but fertile to pollen brought from other flowers of the same species. It is the intention of nature that the insect shall bring from another flower of the same kind, pollen which shall fall upon the stigma and

fertilize the ovules, thus keeping the breed strong and healthy. (See pages 95, 96.)

Fruit-growers are known to object to the presence of bees in their locality, because they think the bees destroy grapes, peaches and other fruits by breaking the skin and sucking the juices. The Department of Agriculture at Washington has given this matter a thorough test by placing hives of bees in a large closed house; here these bees had no opportunity to secure food of any kind. In this house where those starving bees were kept there were hung all varieties of fruits, such as grapes, peaches, apples, plums, nectarines, and many other classes of fruits. Observers were placed beside each kind of fruit to notice the action of the bees thereon. It was universally noted that not a bee was observed endeavoring to cut into any variety of fruit, regardless of the delicacy of the skin; but when the skin was broken by decay or bruise, or any similar cause, the bees naturally inserted their tongues and lapped up the escaping juices.

Wasps.— The horticulturist has many friends within this one order to which the bees belong. There is a great variety of that class of wasps which are known as "mud-daubers" and the like, whose silent work in killing caterpillars and carrying them away as provision for their young is of inestimable value to the horticulturist.

Parasitic Insects.— Then there are those of the bee family which we speak of as parasitic Hymenoptera. These insects lay their eggs upon the backs of caterpillars; the young from these eggs attack the cater-

pillars and kill them. The caterpillars become a "peripatetic banqueting-hall for unbidden guests." Then there are others of this same group which lay eggs among the eggs of injurious insects such as the codling moth, and as their eggs hatch the young larvæ sustain themselves upon the eggs of these injurious forms. Of these Hymenoptera there are no less than four that prey upon the codling moth.

The insect friends of the horticulturist are classed under three heads: as pollenizers, as parasites upon injurious forms, and as predaceous insects preying upon injurious forms. The bee was an example of the first, the ichneumon fly of the second, and chief among the third might be mentioned the ladybirds or ladybugs, about which there is the rhyme,

> "Ladybird, ladybird, fly away home:
> Your house is on fire, your children will roam."

Predaceous Insects.— These bright red beetles with black spots on their backs are preëminently the friends of the horticulturist. The little immature forms known as grubs or larvæ spend their time in eating up plant-lice, scale insects, and many other injurious forms. The adult beetle is no less active. The most remarkable case on record of the beneficial results derived from a single insect is that of a member of this group of ladybirds. A few years ago the citrus or orange industries of California were al-

FIG. 107. "Ladybird" and larva, *Coccinella abdominalis*.

most destroyed. It had come to be considered that the culture of oranges would have to be suspended, owing to the highly destructive work of a certain white scale known as the fluted scale. It was found that the native home of this scale was in Australia. It was observed that in Australia a certain one of these ladybirds subsisted exclusively upon this white scale. A force of men captured a large number of the ladybirds, brought them to California, and distributed them among the orange groves. The result was that in a few years the scale had almost entirely disappeared, and to-day it can be found only in very limited numbers in any place in the State. This condition of affairs is due wholly to the active and persistent work of this little ladybird. Not only has this same insect made orange industries profitable in California, but it has been introduced into Portugal, where it is doing equally good work for the orange groves of that country.

Then there are those beetles which we commonly call ground-beetles (p. 277), always to be found on the ground, some of them of good size and some of them of smaller sizes. They spend much of their time digging about for the eggs of injurious insects, and many of them subsist almost exclusively upon the grubs of injurious forms. Frequently one of these allies meets its death under the foot of some horticulturist who erroneously believes it to be an enemy.

OF THE FARMER.

Farm products are not exempt from the presence of insects both beneficial and injurious. Should the

farmer devote his attention to the production of wheat, just before he is ready to garner it he finds that certain insects harvest a quota proportionate to their

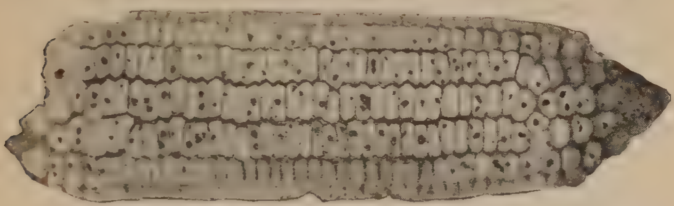


FIG. 108. Ear of corn, showing holes made in kernels by larvæ of Angoumois grain moth, *Gelechia cerealella*. From photograph.

numbers. Chief among these is the chinch-bug, a small dark-colored insect with light-colored wings.

The Chinch-Bug.— Each female chinch-bug lays about 500 eggs promiscuously on the ground early in the spring. These soon hatch as little red, spider-like forms, and seek their nourishment from surrounding plants. They do not eat the stalk, but insert the beak and withdraw the life-juices of the plant, causing it to dry up prematurely. In about six weeks these young red insects are mature, and ready to reproduce their kind. It is this second brood that sometimes makes sad havoc in the grain-fields of the farmer. The question then is, What means of defense are at the disposal of the farmer? He has not many insect allies to aid him in the reduction of this insect. There are certain contagious diseases which break out under certain climatic conditions. These conditions are obtained when the weather continues warm and moist. When these conditions prevail and the chinch-bugs are numerous, great numbers of them will die in a short space of time from contagious diseases. When, however, the weather

Fig. 109. Tar-covered ridge, barrier to advance of chinch-bugs into new fields. The small black mounds to right of ridge are piles of dead chinch-bugs taken from post-holes. Photographed by F. Marcy.

is hot and dry, conditions naturally favorable to the increase of bugs, the farmer must rely upon artificial barriers. Ridges covered with tar or similar adhesive substances placed through the field prevent the insects' advance into new territory, since during their most destructive period they are wingless and must proceed by traveling along the ground. Post-holes placed at intervals along the side of this ridge will trap great numbers of these invading insects. (Fig. 109.) Clean, careful farming, gathering rubbish and burning the same in the fall will remove opportunities for the adult insects to hibernate in security. When this is done many will not live to reproduce their kind the following season.

Grasshoppers. — These frequently cause great destruction to cultivated crops. The most noted among the destructive forms in this country is the Rocky Mountain locust. This insect eludes all effective means of defense, since it is migratory, and appears in hordes without previous warning.

There are, however, many native forms which live and die near the place of birth. These the agriculturist can readily dispose of. The life history of one of these has already been studied. It has been observed that they spend the winter in the egg stage in pods, about one hundred in number, about an inch below the surface of the soil. It is evident that if these eggs are destroyed, no grasshoppers will appear to injure vegetation. This should then be the first point of attack. In the fall the female lays about 100 eggs, in a hole made by herself and extending an inch or so beneath the surface of the

ground. As the female grasshopper lays the eggs, she places an impervious glutinous coating around them. This glutinous material binds the eggs together and surrounds them so as to form a water-proof pod molded to the shape of the hole which the insect has made. If the ground is disturbed in the spring these egg-pods will be broken up, exposed to the sun and rain, to sudden changes in the weather, to birds, and to other insects. All of these conditions are highly injurious to the life of the embryonic grasshopper, and few of these insects

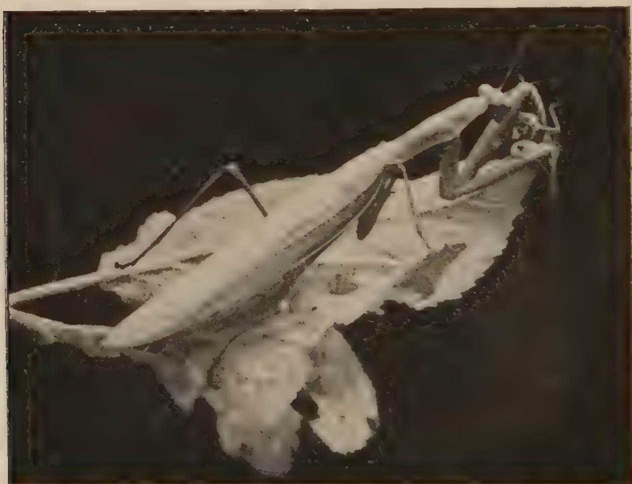


FIG. 110. A beneficial insect. Praying mantis (*Mantis religiosa*) eating live grasshopper which it has captured with its strong, spined fore legs—natural size. Photographed from life by M. V. Slingerland.

will hatch on ground thus treated. If the ground is not disturbed the eggs protected from the winter snows and spring rains by this water-proof coating will hatch; and as small nymphs the young insects will find their way to the surface to begin their work of devastation.

How can we disturb this soil in which the females have placed their eggs? If the ground is to be plowed in the spring this will suffice, but in the case of meadow lands and pastures this cannot be done. In the case of alfalfa, a meadow crop, it has been found that if this

FIG. 111. Beneficial mite. Red mite (*Trombidium locustarum*), an external parasite on membrane of wing of grasshopper, impairing powers of flight. Greatly enlarged.

crop be harrowed in the early spring with a disk harrow, the process greatly increases the growth of the plant, in both root and stalk. This results in a much larger yield of forage. This plant, by reason of its early spring growth, furnishes nourishment for the emerging grasshoppers at a time when, if they had to hop far for succulent food, many of them would perish. So, fields which have grown this alfalfa crop year after

year on undisturbed soil are favorably placed for the increase of these native grasshoppers. There is in the undisturbed alfalfa meadow an opportunity for the quiet hibernation of the egg and the proper nourishment for the young insect. Life under such conditions is free from many of the contingencies which arise in the struggle for existence. Here these insects will be found in undue numbers until they have by continuous defoliation destroyed their means of support, the alfalfa; or until the farmer has interfered and removed them.

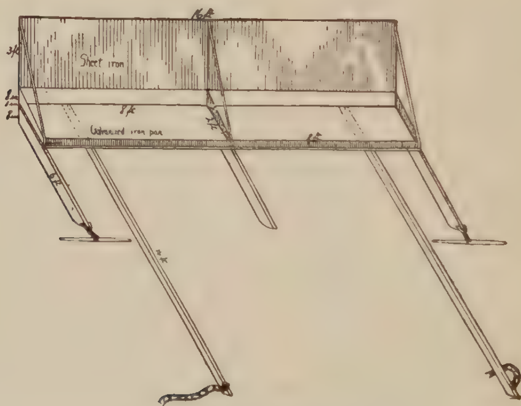


FIG. 112. Plan for hopperdozer.

It may not be possible to destroy all eggs by harrowing and plowing. To insure the destruction of such grasshoppers as may hatch, a machine called the "hopperdozer" is used. This consists of two shallow pans about four feet long, two feet wide and eight inches deep, placed on wooden runners corresponding in height to the crop. At the back of these pans there

should be placed, upright, a sheet-iron or canvas back. This back should be about three feet high. Its purpose is to prevent the insects flying over the pans. When the machine is ready for use, place two buckets of water and half a gallon of coal oil in each pan, hitch one horse to each of the outside runners of the hopperdozer, and then drive back and forth across the field where the grasshoppers are either entering or are at work. As fast as the insects fill the pans, remove, and replenish with oil and water. This cheap and effective mixture of coal oil and water proves deadly to insect life. Where grasshoppers are troublesome, if the farmer will either plow or harrow his land in the early spring, and then in the summer will kill by means of the hopperdozer those that he did not destroy in the egg stage, he will practically destroy all the insects of this kind upon his farm.

The Army Worm. — There is an insect which occasionally appears in great numbers in the caterpillar stage. When in quest of food these larvæ are wont to move in one general direction, eating all vegetation as they go. From these habits this insect frequently gets the name of the "army worm."[1] These insects occur every year, but not always in numbers sufficient to attract general attention. Sometimes, however, the number of eggs deposited early in the season becomes very great, and the larvæ hatched therefrom become so numerous that they are forced to travel in order to obtain food. Their traveling, rolling and piling one over another is not instinctive, but is simply a condition brought about by reason of their great numbers. When

[1] *Leucania* sp.

the brood is few in number the larva finds, without much moving about, sufficient nourishment to satisfy it. When the brood is large, as is sometimes the case, the caterpillars are forced to travel in order to satisfy their natural cravings for food.

These insects are two-brooded. The second or mid-summer brood is the one which furnishes the largest army of worms. Some of this midsummer brood emerge before winter to lay eggs, and others pass the winter in the pupal stage. It is probable that the majority of these insects spend the winter in the larval or pupal state. If the ground is stirred by plowing or harrowing in the early spring, it is evident that the majority of the hibernating larvæ and pupæ will be destroyed. Mechanical means, such as the cutting down of the crop on the edge of the field where the caterpillars are entering, and destroying this crop by fire, are effective, since the larvæ are burned with the crop. The march of this enemy can sometimes be checked by plowing a furrow across its front and dragging a log back and forth through the furrow, crushing the insects as they crawl into the furrow.

FIG. 113. The potato beetle (*Doryphora 10-lineata*).

The Potato Beetle.—An insect which has been of great importance in connection with potato culture is the well-known potato beetle,[1] ten-line beetle, or Colorado beetle. This insect passes the winter in the adult or pupal stage, and comes forth in the early spring to

[1] *Doryphora 10-lineata.*

attack plants such as the potato as soon as these plants appear above-ground. Upon these they lay eggs which bring forth reddish, slug-like larvæ. This brood of larvæ is the one which frequently defoliates the first crop of potatoes. Before the application of arsenites was fully understood, the potato beetle was an enemy of considerable importance. In those days the only means of ridding the potato patch was by hand-picking the eggs and insects. With a more complete knowledge of insecticides, however, we find little or no difficulty in treating the potato plants by spraying with Paris green one pound, freshly slaked lime one pound, water 100 gallons.

Squash-Bug.— In garden crops the squash-bug and the cabbage worm are frequently injurious. The squash-bug[1] attacks and causes considerable injury to the vines of the cucumber. This dull, grayish-brown insect belongs to the order Hemiptera, suborder Heteroptera, and therefore has sucking mouth-parts. The puncture made by the beak of this insect when feeding seems to be peculiarly poisonous, especially to young vines. The insect spends the winter as an adult, and in the spring lays its golden-brown eggs upon the vines of the squash or cucumber family. These insects, as has been previously said, secure nourishment from within the plant, and therefore cannot be poisoned by ar-

Fig. 114. Squash-bug (*Anasa tristis*). Drawn from nature, by Miss M. E. Wise. × 2.

[1] *Anasa tristis.*

senites. They can, however, be reached by what we speak of as contact poisons, the best of which is kerosene emulsion. (For directions for making, see page 305.) This spray is a contact poison, since it kills the insect by coming in contact with its body, and not by entering the alimentary canal as is the case with arsenical poisons. Since these insects spend the winter in the adult stage in rubbish left about the garden plots or fields where vines of this family are cultivated, all such refuse allowed to remain favors their hibernation. In the fall, then, all vines and rubbish about garden plots should be raked up and burned, and in so doing many of the insects will doubtless be destroyed at the same time.

The Cabbage-Worm.[1] — Farmers who are engaged in the production of cabbage for market, as well as those

FIG. 115. Cabbage butterfly (*Pieris rapæ*), parent of the cabbage-worm. Drawn from nature, by Miss M. E. Wise.

who raise only for home consumption, find considerable difficulty with the small greenish worm known as the cabbage-worm. The parents of this cabbage-worm were brought from Europe. They are about one and one-half inches in wing expanse, white or creamy white in color. The male has a single black spot in the fore

[1] *Pieris rapæ.*

wing and the female two black spots in the fore wing. The points of the fore wings are also black. The under side of the wing is usually darker. These butterflies are to be seen in the early spring. They spend the winter in the pupal stage. They lay their eggs generally upon some one of the plants that belong to the mustard family. These eggs hatch and the insects come to maturity in time to lay their eggs upon the early cabbage plants. Their presence is soon told by the ugly holes which appear in the outer leaves of the growing cabbage plant. The caterpillars themselves show their protective characteristics in a marked degree, in that when feeding upon the cabbage leaves they resemble the leaf so nearly in color and lie so closely to the plant tissue that they are easily overlooked. They can be destroyed, however, by the arsenical spray described on page 303. This is an effective remedy, and can be applied in the spring without fear of the poison remaining there to endanger the lives of persons who will later eat the cabbage, if applied before the cabbage-head has formed.

Some Beneficial Insects. — These are some of the principal insect enemies of the farmer. He, like the fruit-grower, has friends among the insects, and these friends are of the same general character as those of the fruit-grower, viz., destroyers of noxious insects, by preying upon them, by being parasitic upon such injurious forms, and as pollenizers of the various crops. In addition, certain other insects are beneficial in that they eat and therefore destroy certain noxious plants. An illustration of beneficial results derived from the predaceous

—10

and parasitic insects may be taken from the fact that the army worm rarely appears in considerable numbers two seasons in succession, showing that these enemies severely check its increase. There are a number of flies somewhat similar in appearance to our common

FIG. 116. Different stages in transformation of parasitic fly (*Sarcophaga* sp.): *1*, *2*, *3*, *4*, white maggot in active stage; *5*, maggot beginning to pupate—dirty white in color, pupa-case light brown; *6*, *7*, fully developed pupa-case of two species. × 5.

house-fly. These flies are parasitic upon grasshoppers, and aid in keeping the grasshoppers in check. Some of these flies are illustrated in Figures 117 and 171. In regard to pollination of crops, reference has already been made to the fact that the honey-bee materially increases the yield of the alfalfa plant. (See page 107.) It is known that the bumblebee is very influential in bringing about the proper fertilization of the common red-clover blossom. However, injurious insects, such as the grasshopper, may not be looked upon as wholly injurious, since they frequently furnish food for the farmer's poultry. High-class farm culture tends to reduce the numbers of injurious forms, and at the same

time gives better crop yields. The work of destructive insects is not a total loss, since the part of the crop left will bring a price somewhat higher than if the whole crop had been placed upon the market. This is in the case of a general devastation by insects. From this standpoint neither the individual who lost his crop nor the State that lost its crop would be benefitted, but the individual or State that harvested a part or all of the crop would be benefitted by the rise in price caused by its scarcity, this scarcity being due to the work of injurious insects.

FIG. 117. A fly, parasitic on grasshoppers. Enlarged.

OF THE HOUSEKEEPER.

The House-Fly.—Among insects, probably the one causing most general annoyance to the housekeeper is the house-fly. There are several species which are given this name, but the one most abundant is that known to science as *Musca domestica.* It is the ordinary grayish fly, with mouth-parts separate at the tip for sucking up liquid substances. It is not within the power of this species to pierce the cuticle. There is, however, an opinion prevalent that it can bite. This is not due to any of its actions, but to the resemblance of another fly, sometimes found in the house, a fly known as the stable-fly.[1] This stable-fly is probably next in point of

[1] *Stomoxys calcitrans.*

abundance to the house-fly in most portions of the United States. The greatest structural difference between the two is that the stable-fly has mouth-parts adapted for piercing the skin. The house-fly has no piercing organs in its proboscis.

The common house-fly breeds in fresh horse-manure, from which during the warm weather the generations emerge in quick succession. It is well, then, to prevent the prevalence and avoid the annoyances arising from the presence of this insect by seeing that all stables in the vicinity are kept perfectly clean, and the sweepings therefrom promptly removed or well covered with lime. As is well known, these insects can be practically excluded from the home by means of wire mosquito netting over the doors and windows.

The house-fly has a number of natural enemies, some being hymenopterous parasites, others being predatory beetles. The enemy which most effectually reduces the house-fly, however, is a fungous disease characterized by the whitish swelled abdomen of the dead insect. This disease does not generally become epidemic until late in the season.

The Buffalo Moth.— In some parts of our country the buffalo moth[1] or carpet beetle creates considerable damage among woolen goods. Like many of the common names given insects, the term "buffalo moth" is misleading. This buffalo moth is not a moth, but belongs to the Coleoptera. In the summer and fall these insects are the most active, but in well-heated houses they may work throughout the year. The adult insect is a broad oval

[1] *Anthrenus* sp.

beetle (Fig. 119), three-sixteenths of an inch long, with a brick-red irregular stripe down the middle of the body. The wing-covers are black, but covered with minute whitish scales which give them a marbled black appearance. The beetle itself is a day flyer, and feeds

Fig. 118. Buffalo moth larva. This is the stage in which the insects cut carpets, woolen goods, etc. Drawn from nature, by Miss M. E. Wise.

Fig. 119. Buffalo moth beetle (*Anthrenus scrophulariae*). Drawn from nature, by Miss M. E. Wise.

upon flowers such as the golden rod. The insect itself is not troublesome to the housekeeper. It enters her house to lay eggs in crevices or in the vicinity of woolen goods. These eggs hatch as reddish brown, hairy, oblong forms, which apparently have no head or feet. (Fig. 118.) The feet and head, however, are fairly well concealed beneath the bristly covering. The larvæ have mouth-parts well developed for chewing. It is in this larval stage that the cutting of carpets and other woolens takes place. This insect is one of the most troublesome household pests to be found in the United States. Whenever a house becomes badly infested it frequently is necessary to abandon the use of

carpets for a time and use rugs in their stead. These rugs will require frequent exposure to the sun. Where the insects are quite general the carpets should be taken up, thoroughly beaten, and carried out of doors, sprayed with benzine, and allowed to air for several hours. The benzine is a very volatile substance and highly inflammable, so that due care should be taken to keep away from lighted substances while this work is being carried on. The rooms themselves should be thoroughly swept and dusted, and the floors should be washed with hot water.

The Clothes Moth.—A destructive insect among furs and woolen fabrics is the well-known little clothes moth.[1] Fur and woolen garments are its favorites. In its attacks upon these, possibly it has become the most generally known household pest. It does not confine its attacks to the home alone, but is likewise to be found in the dry-goods store. The moth is a little buff-colored lepidopteron, being about three-quarters of an inch in wing expanse. These moths in themselves are harmless. Like the buffalo moth, however, the larva or caterpillar is the one which commits the depredation. In the North there is but one annual generation, the adults appearing from June to August; in the South we find there are two or even more broods annually.

The larva is a dull-white caterpillar, and is never seen away from its movable case. (Fig. 120.) The construction of this case is its first task. If it desires to change its position it thrusts out its head and thorax, and by means of its thoracic leg drags itself to the de-

[1] *Tinea pellionella.*

sired location. As the larva grows it finds it necessary to enlarge its case both in length and circumference. The way it does this is rather interesting. Without bursting its case the larva makes a slit half-way down one side, and inserts a triangular gore of new material.

FIG. 120. Larvæ of clothes moth feeding on felt. Photographed from life.

A similar insertion is made on the opposite side. The larva revolves itself without leaving the case, and makes corresponding slits and additions in the other half. It lengthens its case by adding to either end. In appearances the case looks like a matted mass of wool. If the interior be examined it will be found to be lined with soft white silk. If the larva is transferred from time to time to fabrics of different colors, the cases may be made to assume as varied a pattern as one desires. The varied colors will illustrate the peculiar methods of enlarging just described. The fully developed larva about to pupate attaches itself by silken threads to the garment upon which it has been feeding,

or to some object near by. It emerges as a moth about three weeks later. The moth flies in an irregular manner, but can run well over clothing when disturbed. The moth prefers darkness, and successfully conceals itself in dark folds of the garments or in crevices when disturbed.

Unfortunately, there is no good method of preventing the damage done by these insects. Constant vigilance and frequent inspection are demanded whenever these insects become troublesome. The various repellents, such as camphor, moth-balls, tobacco, etc., are of little value if the garments are already stocked with eggs, since these will hatch and mature regardless of the odor. The moths, however, are repelled from depositing their eggs while these odors are strong. But if the moths are inclosed with garments protected by these repellents they will naturally lay their eggs and the destructive work of the larva will soon begin. The remedy which seems to be the most satisfactory, though attended by a good deal of trouble, is to sun and brush thoroughly all winter clothing, then place away in large boxes such as tailors use, and seal the boxes up by gumming a strip of wrapping-paper around the edges so that the boxes will be completely sealed up and leave no cracks. In this way the insect is denied entrance, and therefore no damage is done.

The Cockroach. — Then there is the wary and troublesome cockroach. So well known are they as to make a description unnecessary. Various poisons, such as phosphorus paste spread on cardboard and placed in the runways of the roaches, have been used with fair

success. Wherever the apartments infested are small and can be tightly closed, these insects can be killed by fumigation with carbon bisulphide, a volatile and highly inflammable substance. Therefore great care must be taken to keep lighted matches away from its gases. Place the substance upon pans in the room, and then close the room and the substance will evaporate. If used in sufficient quantities this carbon bisulphide will kill the insects. It is very necessary, however, that the room be made tight, in order that none of the gas may escape. It requires a strong gas to kill the insects.

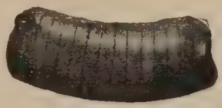


FIG. 121. Egg-pod of cockroach.

House Ants.—Another form which proves troublesome in the cupboard and on the pastry shelves is the ant, and of these there are a number of species which frequently prove troublesome to the housekeeper. Carbon bisulphide poured upon the hole from which they emerge, —this is the entrance to their nesting-place,—will effectually free the house of them. If, however, their nests cannot be found, it becomes necessary to destroy them whenever they are found in the house. This can be done by placing large sponges in situations where the insects are most numerous; these sponges, being saturated with sweetened water, will collect the ants in great numbers. The sponges can be placed in hot water several times a day, thus killing the ants.

OF MAN IN GENERAL.

While the foregoing insects indirectly affect man himself, there are some which directly have to do with his comfort or discomfort. There are very few habitable regions where man is not personally subject to more or less annoyance from insects. In this part of the world we at once think of mosquitoes.

The Mosquito.— The eggs of the mosquito are depos-

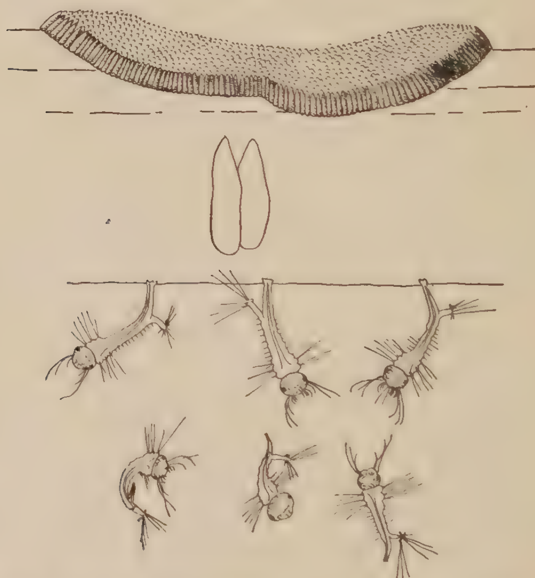


FIG. 122. Mosquito (*Culex pungens*) in process of development: Egg mass above; two eggs, much enlarged, just below; young larvæ, enlarged, below. Three of these are represented as at the surface of the water breathing through the caudal tube or trachea. (After Howard.)

ited in small boat-shaped masses, and the young hatching from these escape into the water. We frequently find the half-empty rain-barrel well supplied with these larvæ, commonly called "wigglers." These move about

by a jerky motion, ascending at times to the surface for a supply of air. This they take in through a slender tube at the caudal end of the body. The pupæ are active, and can readily be distinguished from the larvæ. The head of the larva or wiggler is not naturally large. The pupal head has the feet and developing

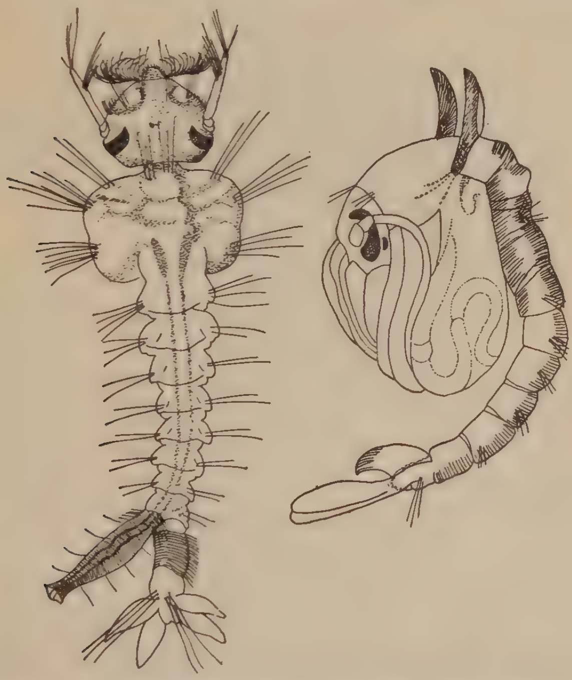


FIG. 123. Full-grown mosquito larva on left. Pupa on right. Much enlarged. (After Howard.)

wings folded around it, so that the pupa is quite easily distinguished from the larva by the size of its head. This distinction can be made as the insects are observed in the water in the basin in which they have been col-

lected. The pupa takes air through a spiracle near the head. When the insect is ready to emerge, the pupa rests at the surface of the water, the dorsal portion of the body slightly out of the water. The pupal case splits, and the mosquito draws out first the fore legs, which are placed on the water to serve as a support while the rest of the body is withdrawn. The wings expand quickly,

FIG. 124. Mosquito (*Culex pungens*), female. (After Howard.)

and the insect flies away. The pupal case serves as a raft upon which the insect floats momentarily while the wings are drying. Should there be a brisk wind at this moment, the insect will be blown from its raft and drowned. This is not an infrequent calamity in the life history of the mosquito.

In the matter of remedies we are all familiar with the use of mosquito netting over doors and windows of dwellings. The best means of dealing with the mosquito are preventive. Rain-barrels should be kept securely covered. A rain-barrel allowed to stand open with sufficient dregs will furnish a breeding-place for enough mosquitoes to torment a household. There are three principal remedies: standing pools can be drained; ponds can be well stocked with fish; or kero-

sene, about one ounce to fifteen square feet of water, can be poured over pools of water which cannot be readily drained. If the ponds are drained the breeding-places are ruined. If fish are introduced they feed upon the larvæ and pupæ. If the surface of the water is given a coating of kerosene, the pupæ, as they come to

FIG. 125. Mosquito (*Culex pungens*), male. (After Howard.)

the surface to emerge, will be killed, and the female depositing her eggs on the surface will come in contact with the kerosene. This will destroy her before she has had an opportunity to deposit her eggs. These are three effective remedies. The one best suited to the occasion can be chosen.

Mosquitoes are looked upon as annoying only in so far as they directly disturb man. There are good reasons for believing that mosquitoes may act as disseminators of disease. It has been partly proven that mosquitoes

breeding and living in the swamps introduce into the human body with the insertion of their beaks that which brings on malarial fever in the person bitten. Insects as carriers of disease is a subject only coming to be understood and studied. Bites of the horse-fly[1] and the stable-fly[2] have developed into grievous pustules, showing germs of anthrax, a malignant contagious disease, transmissible from cattle to man and from man to cattle. Insects which frequent or breed in decaying animal or vegetable matter should certainly be kept from contact with man and his food.

This phase of insect injury is to be classed as of the greatest importance, and is a subject which deserves the notice and attention of every one who cares for cleanliness and health.

Beneficial Insects. — Insects are not wholly injurious when viewed from the standpoint of man. As scavengers they render humanity invaluable service. The services of certain insects in doing away with and rendering harmless dead matter of both plant and animal origin are inestimable. Linnæus, the great naturalist, stated that the offspring of three blow-flies would destroy the carcass of a horse as quickly as would a lion. This statement may be somewhat exaggerated, yet it serves to illustrate the good offices of insects. Certainly the offspring of the blow-fly would leave the carcass of the horse in a much less offensive condition than would the lion. Large groups of insects play an important part in cleaning up and removing decaying matter which, if allowed to remain, would certainly

[1] *Tabanus.* [2] *Stomoxys.*

prove detrimental to health as well as highly offensive to the senses.

Insects are further valuable to man in that they furnish food. Chief among the insect foods used by man may be cited honey from the honey-bee,— a notable article of food upon which is based a great and world-wide industry. Many insects furnish food for poultry, fish, and song-birds; being therefore indirectly beneficial to man.

In the matter of clothing it is well to know that our silk is derived wholly from insects. The delicate silken fiber of which the cocoons of the silk-worm are made, is the crude material from which the silk of commerce is manufactured.

The cochineal dyes, formerly so greatly used, are insect products. Shellac and Chinese white wax are likewise products of insects.

These are some of the principal relations which exist between man and insects. Man is the dominant type, and his appearance directly or remotely changes the whole train of natural laws. We can readily see the sequence in the statement of Wallace, that the more old maids the more abundant the clover-seed crop, for the maids protect the cats which kill the mice which rid the nests of bumblebees which fertilize the clover-seeds.

In our study of injurious and beneficial forms it becomes essential that we acquaint ourselves with the life histories of the insects which affect us either beneficially or otherwise, in order that if a check need be made, we may be aware of the most vulnerable point of the injurious insect. We should likewise become acquainted

with the structure and feeding habits of the insect. If the injurious insect has mandibles and masticates its food, it can then be reached by poisoned baits, or by poisonous sprays thrown upon its food plants. If the injurious form procures its food through a sucking-tube, we then must use contact poisons,— those which destroy the insect by coming in contact with its body. We should likewise become acquainted with our friends in the insect tribe, in order that we may at all times favor those which favor us. This whole subject is included under the head of economic entomology — a phase of the study inviting to young students.

In this study there should be at all times an attempt to reach the proper point of view; that is, the causes and effects. For instance, the short-sighted fruit-grower is sometimes prone to overestimate the evils attending his vocation; some are wont to recall the "good old times" when none of these pests existed. These fruit-growers forget that in those times there were no orchards, and that the apple industry was represented by a few seedling trees growing about the pioneers' log cabins. The farmer likewise sometimes becomes disconsolate by reason of the unexpected attacks of an invading insect horde. There is behind these attacks some cause. The farmer has probably continued to raise throughout a series of years, upon the same ground, the food plant of the invading insect. Had there been frequent rotation of crops this state of affairs would have been avoided. In reality, then, the agriculturist himself is at fault for the undue prevalence of the injuring forms. If flies become exceedingly troublesome around

the house, it will be advisable to inquire into the conditions of the stables in the vicinity. Properly kept stables will greatly reduce the number of flies.

It will be found that gregarious insects do not appear in such great numbers year after year: there must be some cause for this. It will be an interesting problem to be solved.

The enemies of insects increase as well as the competitors. Parasites, attracted by innumerable insects upon which they prey, increase so rapidly as to devour their own means of support. They in turn succumb and the defeated host rallies; so the alternate warfare goes on forever. And in the activities of these beings which we are wont to consider beneath us, there is much for profitable observation and careful study.

CHAPTER IX

THE WEALTH OF INSECT LIFE—ORDERS

Insects, numerically considered, comprise four-fifths of the animal life of the globe. There are now about 250,000 species to which names have been given. This number, it is estimated, is about one-tenth of the existing forms. If we look at a number of these we find great differences in appearance and structure. If an examination be made of those which at first glance appear to be similar, marked distinctions arise. For example, we frequently strike at a fly biting the back of our hand, thinking it to be the common house-fly, while in reality the common house-fly has not the necessary mouth-parts to enable it to pierce the cuticle. Again, we might find two insects apparently widely separated by color, or structure,—distinctions due to the character in the sexes of the same kind of insect. Then if we change the food and surroundings of an insect, we soon find a subsequent generation of this insect changing in form and appearance. The sheep tick, a wingless, almost grub-like insect, was once a two-winged fly, but on account of its parasitic habits it has lost its wings through disuse. Other forms, such as the viceroy butterfly (Fig. 48, *b*), have changed their outward appearance. If we remove an insect to a new country we find changes arising, due largely to changed climatic conditions.

And so in classification, we find it difficult at all

times and under all circumstances to recognize forms possessing blood relations sufficiently intimate to enable them to reproduce in kind through successive generations. We must not expect or look for absolute identity among individuals of the same species or kind. We should be satisfied with an agreement in the most essential features. Then if the question arises concerning the essential features of a character, it will have to be said that the essentialness of a character is to be found in the constancy of its reappearance as successive generations come forth. Upon such considerations is a species based.

But as has been suggested, species themselves change. Within species we find varieties, which in time, we may suggest, will continue to vary, for one or several of the reasons stated, in a fixed direction until their essential characteristics will be so diverse from the mother species as to constitute a species themselves. There seems to be a tendency in nature to encourage, as it were, this divergence. If all forms of one species of insect were identical, all would be common prey to the same enemies. That is, if a certain parasitic insect or bird always attacked a certain species, these being all the same, none would escape through the faulty recognition of the enemy. But since this tendency to vary exists, some escape by reason of dissimilar features, which enables them, temporarily at least, to elude the recognition of the enemy. And so those escaping by reason of these variations are consequently liable to reproduce these variations in their offspring, until the variations become fixed. Under such circumstances we consider that a species has been developed. Individuals, then,

which constitute a species are those which do reproduce in kind through successive generations. To ascertain the powers of insects in this direction would be a very difficult task. So for the most part, at present, specific distinctions are based upon characters which, being present in a large number of closely allied individuals, are considered constant.

Groups of closely allied species are arranged together under one genus; then closely allied genera are placed in a group called a family; and families with leading characteristics in common form an order; and orders, for the same reason, compose a class; and classes a branch; and branches a kingdom. This may be termed artificial; and in part the arrangement is artificial, but the endeavor is to discover the natural grouping. The classificatory position, then, for instance of our familiar robin, might be sketched thus:

ANIMAL KINGDOM.

Branch, *Chordata* (Vertebrata).	Family, *Turdidæ*.
Class, *Aves*.	Genus, *Merula*.
Order, *Passeres*.	Species, *migratoria*.

The term Robin is the common or vernacular name; the scientific name, the one intelligible to ornithologists of all nations, is *Merula migratoria*. And so in speaking of any one form two names are required, the first to designate the genus, and the second term the species. Varieties are known as subspecies, races, or varieties.

It will be our purpose to acquaint the student with the principal orders and families of insects, and in so doing the attention is called to the steps to be taken from order and family before species is reached. The system used is an old one, and takes for its basis of

differentiation the character of the organs of flight, and the structure of the mouth-parts. Exceptions to the arrangement can be found in every order given. The same may be said of any system thus far proposed. This method commends itself for its simplicity and the uniformity of its nomenclature.

Insects, then, according to this system are grouped into nine orders, and the names of these are formed of words compounded with the Greek root, πτερόν, pteron, meaning wing. These are: Aptera, Neuroptera, Orthoptera, Thysanoptera, Hemiptera, Lepidoptera, Coleoptera, Diptera, and Hymenoptera. The character of the mouth-parts is designated by the terms *biting* and *sucking*, the former referring to that form of mouth in which the mandibles and the maxillæ, or either one, are used in grasping, biting or masticating the food; the latter pertains to that form of mouth adapted for sucking. A discussion of the chief characteristics of these orders is given, and some of the more prominent subdivisions, as well as characteristic forms, are briefly treated.

APTERA.

This term, Aptera, is derived from *a*, without, and πτερόν, pteron, a wing. The insects coming under this order are therefore wingless. Mouth-parts mandibulate, metamorphosis slight, the adult form being the same as the larval form. They have a delicate outer skin, sometimes covered with scales. Though somewhat primitive in form, they are so diverse in their individual structures that it is difficult to frame a definition which will include all the group. While it is true that

all are wingless, the order does not include all insects without wings. The term wingless, as used in reference to the Aptera, designates those forms, wingless in themselves, and descendants of ancestors which at no time possessed wings. Among the winged orders, wingless forms are found. Such forms, it is believed, have descended from winged ancestors.

The Fish Moth.[1] — Of this order the forms which the student will most likely meet will be those frequently found in the pantry, in dark closets and damp places. Housewives frequently term them fish moths. If an examination with a microscope be given, they will be found to be covered by shiny scales not unlike those of a fish, and these scales frequently give them a silvery appearance as they move away when disturbed. They are sometimes called bristle-tails, by reason of the three long bristle-like appendages at the caudal end of the body. (Fig. 126.) While some forms live in the house in pantries and in book-cases, or behind wall-paper, feeding upon starchy substances wherever found, others are to be found out of doors under stones and loose bark.

FIG. 126. A fish moth. (*Lepisma* sp.)

The Springtail.[2] — The springtail is the common name given to another group belonging to this order, so called by reason of its ability to spring suddenly. This power is given it by a tail-like organ attached to the end of the body. This tail extends beneath the

[1] Suborder, *Thysanura*.

[2] Suborder, *Collembola*.

body almost to the head. (Fig. 127.) When this is straightened out the insect is propelled several feet forward. Frequently numbers of these little creatures like minute specks can be seen upon snow. To such the name snow-flea is applied.

FIG. 127. Springtail (*Corynothrix borealis*). (After Tullberg.)

NEUROPTERA.

Insects with two pairs of membranous wings, biting mouth-parts, metamorphosis complete in some divisions and in others incomplete. The name arises from *νεῦρον*, neuron, nerve, and *πτερόν*, pteron, wing. The wings, accordingly, are in many cases noticeable for the great amount of net-work. The front wing and the hind wing of the same insect are frequently alike in form, texture, and neuration. This order includes many heterogeneous insects, and is an order which has been subdivided by some authorities into a number of other orders. It includes such forms as the dragon-fly, May-fly, stone-fly, white ant, caddis-fly, and lacewing-fly. A wingless form, the bird-louse, is included here. A better understanding of the scope of the order will be gained by a treatment of a few representative forms.

May-Flies.[1] — These insects, as the illustration will show (Fig. 128), are characterized by two pairs of membranous wings, the hinder pair being much smaller than the front pair, and by the presence of two long, thread-like abdominal appendages. They are peculiarly

[1] Family, *Ephemeridæ*.

interesting insects in the matter of their life history. The adult has an ephemeral life, lasting for a day or so at most. The females of some species drop their eggs upon the surface of the water, and others drop their eggs beneath the surface on stones. The young nymph — not at all like its parent — hatches and lives in the water, feeding upon water plants or minute insects for from one to three years according to the species. They come forth at maturity, and can be found in great numbers in the warm summer evenings around the electric lights or upon the trunks of trees in the vicinity of water. Catch one of these adult forms and note the delicacy of its body. Examine its mouth-parts, and note that they are extremely rudimentary or even wanting, a condition brought about by disuse, since the life of the adult has become of such short duration that the necessity for taking food is no longer urgent. These insects are exceptional in their life history, since they molt once after having reached the winged stage.

FIG. 128. A May-fly. From a photograph. Enlarged.

Stone-Flies.[1] — In structure of wings these insects resemble the May-flies. The net-work of the veins

[1] Family, *Perlidæ*.

is frequently much less, and the hind wings are always more fully developed, folding in plaits on the body when the insect is at rest. The mouth is fitted for biting, the parts frequently being rudimentary.

The form in which these insects are most readily observed is in the nymphal stage, when they can be

FIG. 129. Stone-fly nymph.

FIG. 130. A stone-fly (*Perla ephyre*).

found under rocks, stones or logs in brooks. They are not at first observed, so closely do they cling to the overturned stone or log. Remove some of them to a bottle of water. How many legs have they? Of what use are those fringes along the under side of the body?

The White Ants.[1]—While these are called ants, they are not closely related to ants. Like ants, however, they are social, and are represented by queens, kings, workers, and a form not found among ants,—the soldier.

[1] Family, *Termitidæ*.

FIG. 131. White ants. Soldier on the left, worker on the right.

The workers, as the term suggests, perform the labors of the colony. The soldiers are the defenders of the home. Upon the king and queen depends the increase of individuals.

Kings and queens are winged. In May and June those individuals belonging to our species in this country leave the nest by flight and select new locations. A king chooses a queen. They shed their wings. If perchance a few workers find them and adopt them, the workers will build a circular cell for protection and furnish them food. This procedure forms the basis for the establishment of a colony. Since workers do not always discover and adopt these noted individuals, many kings and queens perish unattended. Should a colony become queenless, wingless, sexual individuals, complimented kings and queens, are produced. Such females are unable to lay many eggs, and here we find several of these required in the colony to fill

FIG. 133. White ant queen, from Africa — natural size. From photograph.

FIG. 132. A king white ant. Enlarged.

FIG. 134. Nest of white ants on post, denoted by arrow on left; locality, Cuba. Photographed by M. V. Slingerland.

FIG. 135. White ants' nest on trunk of tree, denoted by arrow on right; locality, Cuba. Photographed by M. V. Slingerland.

the place of a properly developed queen. In this country white ants are to be found under logs and stones, not infrequently associated with our common ants. Here they do not grow so large, nor are they so numerous as they are in tropical countries.

Dragon-Flies,[1] or "snake doctors," frequently so called, are familiar objects about ponds and quiet streams. In some species the females skim along over the surface of the water, dipping down to the water to drop an egg, there to hatch, and, in the form resembling

Fig. 136. Dragon-fly (*Libellula pulchella*)—natural size. From a photograph.

the figure (Fig. 140), to seek a livelihood. Other females oviposit by descending some water plant until the tip of the abdomen is below the surface of the water, there placing the egg in a slit cut in the plant for the purpose.

Among the weird superstitious beliefs of childhood, and not infrequently of later years, the dragon-flies have a place. Nearly every boy will tell you that the

[1] Family, *Libellulidæ*.

chief end of this insect is to feed the snakes which lie in wait for him. It is a "snake-feeder" in the boy's parlance. Children generally are wont to fear this insect; they call it the "devil's darning-needle." They have been told — and they believe it — that the long tail-like abdomen is a needle with which the insect sews up children's ears.

FIG. 137. A damsel-fly, a Libellulid that rests its wings along its back. The dragon-fly rests its wings at right angles with its body.

Entirely at variance with these strange tales, the insect is not only harmless but highly beneficial, since one of its chief sources of food is the mosquito, with whose piercing propensities all are familiar. When the day is clear and still and the vertical rays of the sun make one content to rest a while in the shade of some spreading elm near the pond lily's home, or down by some sluggish stream, then it is, and there, that the dragon-flies are most active,— skimming along over the water, darting up, then down, right about face, all so quickly that at times the eye can scarcely follow. Suddenly one of them may halt to rest upon a stick or stump rising above the surface of the water, or a dead limb overhanging,— to rest, probably, but more likely to train the eyes on the surrounding space in quest of passing mosquitoes or buzzing flies to be swooped down upon. Thus these dragon-flies are sometimes called "mosquito-hawks." Not unlike the raptorial birds, dragon-flies appear to have a certain stick or stump as lookout for prey. If

the dragon-fly is disturbed it will fly away, to return shortly. This trait furnishes excellent opportunities for taking its picture in its native haunts. The perch discovered, the camera can be set and focused; when all is quiet the insect will return, and the mere pressure of the bulb furnishes a plain picture such as this photograph, taken in a similar way.

FIG. 138. Dragon-fly on the lookout for prey. Photographed from life.

The dragon-fly's biography, could it tell it, would be full of strange incidents and hairbreadth escapes. It comes from a tiny egg, dropped alone in some large pond to hatch and grow. Two problems at once are presented — to secure a livelihood and to escape its hostile water neighbors, among them the fish and other members of its kind, both ready to feed upon it. It first lives upon micro-organisms of the water, but later becomes much larger and stronger and able to capture "wigglers" such as are to be found in rain-barrels. Its under lip is well adapted for this work; it is scoop-shaped, capable of extending and scooping in a wiggler and then drawing the catch up to the mouth, where the jaws make short work of it. (Fig. 139). And if perchance alone and unaided it has been able to escape its enemies and secure enough food to bring it

to the fullness of that water stage, it ascends some reed during the night, and about dawn its back breaks open and out creeps slowly and apparently painfully the dragon-fly, perfect in form but limp and colorless. The bright sunlight, already appearing, soon hardens its skeleton structure and brings out the characteristic colors of the parent insect which dropped the egg in the pond.

FIG. 139. Side and top view of head of nymph of dragon-fly, showing scoop-shaped jointed appendage of lower lip, with pinchers at end. With this the nymph catches "wigglers" and other prey.

Mallophaga.[1]—Bird-lice have, by reason of their parasitic habits existing through a long period, become so highly specialized as to have little in common with other members of the group. Bird-lice must not be confused with true lice. The former have biting mouth-parts, the latter haustellate. The word Mallophaga is derived from two Greek words, meaning, to eat wool. These insects have incomplete metamorphoses, are wingless, and as external parasites feed upon the feathers, hair or skin of the host. They are to be found upon both birds and mammals.

FIG. 140. Skin of nymph from which dragon-fly has emerged.

FIG. 141. A bird-louse (*Eurymetopus taurus.*) This form lives among the feathers of the albatross.

Caddis-Flies.[1] — These moth-like insects, small and rather unattractive, are not frequently noticed. Though possessed of two pairs of well-developed wings, they do not use them readily in flight, so that the adults rarely wander far from their place of emergence in some stream, brooklet, or pool. The mouth-parts of the adult are rudimentary, the metamorphosis complete. The eggs are deposited in a mass surrounded by jelly. Sometimes this mass contains as many as one hundred eggs.

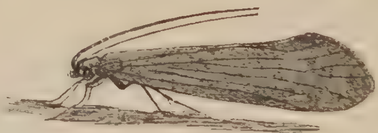


FIG. 142. A caddis-fly (*Leptocerus dilutus*).

Of greater interest than the adult, will be, to beginners, the larva and its habits. The young caddis-worm protects itself from fish and other enemies by constructing a house of sticks, pebbles, leaves and the like, to be found in the water where it lives. The figure (Fig. 37) represents but one of the many interesting houses. Among the stones through which the waters of a small stream is running such forms live.

ORTHOPTERA.

Insects of this order have biting mouth-parts, two pairs of wings, the front wings being generally narrow and the hind wings of more delicate texture, and fold fan-like under the front wings; incomplete metamor-

[1] Family, *Phryganeidæ*.

FIG. 143. The home of the stone-fly and the caddis-fly.

phosis. It includes such forms as the cockroach, earwig, praying mantis, walking-stick, cricket, katydid, and grasshopper. The term is derived from ὀρθός, orthos, straight, and πτερόν pteron, wing.

ORTHOPTERA THAT WALK.

Cockroaches.[1]— These insects are known to every housewife. They are most active at night-time, and readily learn the paths leading to the pantry shelf. The eggs are all laid at once, within a brown capsule. (Fig. 121.) Many species are wingless.

Praying Mantis.[2]— The Praying Mantis possesses many appellations. The fore feet, well developed for

FIG. 144. Young mantis on lookout for prey — natural size. Photographed from life by M. V. Slingerland.

grasping, the elongate prothorax and prominent head, capable of rotary motion, certainly give these insects, to say the least, a strange appearance. They are rather sluggish in their movements, except when an approaching fly reaches a point within their grasp. All these insects are carnivorous. The eggs are laid side by side until they form a mass upon some object such as a fence-board, rail, or limb of a tree. The young escape readily, leaving the egg-mass in form but showing the openings from which the insects come. The mantis family vary in color from dark brown in some to light

[1] Family, *Blattidæ*. [2] Family, *Mantidæ*.

green in others. Some of these insects illustrate protective characteristics to a high degree in their resemblance to leaves of trees. Such forms are confined to the tropics.

"Praying mantis," "praying horse," "mule-killer," "devil horse," "rear horse," and "camel cricket" are

FIG. 145. Full-grown mantis patiently waiting or "praying" for an opportunity to seize any small, unwary creature. Natural size. Photographed from life by M. V. Slingerland.

a partial list of the terms referring to the insect represented in the figure. It has been called by scientists, *Phasmomantis carolina*. The attitude doubtless accounts for the modifying term "praying." "Rear horse" and "camel cricket" have some reference to its shape. The term "mule-killer" arises from the superstition that the dark-colored saliva which the insect ejects from its mouth is fatal to the mule. It is

not easily understood how those familiar with the character and temperament of the mule could readily put their faith in this doctrine.

This formidable-appearing insect can sometimes be found in a quiet corner of the window, in an attitude somewhat like the one here shown. If prayer there be, the petition is surely for the approach of an unwary house-fly to be readily pounced upon for the next meal. This insect is perfectly harmless.

Walking-Sticks.[1] — Walking-Sticks likewise possess characteristics which unquestionably protect them and thus favor their existence. Their long, stick-like bodies and inactive disposition allow them to simulate sticks; or when on trees, the twigs. In the tropics we find the wings of some of these forms simulating leaves. The common form in the North is wingless. The walking-sticks are vegetable-feeders. The eggs are dropped singly upon the ground. (See Fig. 47.)

The foregoing proceed by walking or running; crickets, grasshoppers and katydids have the hind legs fitted for leaping, and while capable of walking they generally move about by jumping.

ORTHOPTERA THAT JUMP.

Crickets.[2] — Crickets are to be found in the harvest-field, under the shocks of grain, and around the stacks. Not infrequently one enters the house, and then, if it be a male, his clear, shrill "click, click" (page 45), his mate-call, notifies you of his presence. These are the familiar black crickets, that live mostly upon the ground. The family contains two other kinds — the

[1] Family, *Phasmidæ*.

[2] Family, *Gryllidæ*.

mole crickets, which live under the ground, in burrows of their own making, feeding upon the tender roots of plants; and tree crickets, which live aboveground, in bushes and trees. In the early spring the eggs of one of the tree crickets can be found in the raspberry canes. (Fig. 36.)

FIG. 146. A mole cricket (*Gryllotalpa borealis*)—one and one-half times natural size.

Katydids.[1] — Katydids, likewise, are musical, night being their time for song. (Page 44.) They live in trees, and from their color resemblance to foliage are not readily observed. Belonging to this same family are others, which resemble grasshoppers. Such are

FIG. 147. Angular-winged katydid—natural size.

easily distinguished from grasshoppers by the length of the antennæ, which are longer than the body. This

[1]Family, *Locustidæ*.

group, then, is sometimes called the long-horned grasshoppers. Grasshoppers proper have antennæ shorter than the body.

Grasshoppers.[1] — Grasshoppers are among our most common insects. The life history of one of the species has already been given. (Page 3.) Those living in this country can be separated into three groups, depending upon the structure of the adult. One group embraces all those without extended ridge on longitudinal median line of pronotum, and bearing tubercle on center of prosternum (*Acridiinæ*). The yellow grasshopper (*Melanoplus differentialis*) is an example. The second is without prosternal spine, and has an extended ridge upon the pronotum (*Oedipodinæ*). The "dusty hoppers," so common in the roadways, belong to this group. The third are not so generally known, but are easily recognized by the backward and downward receding front of the head (*Tryxalinæ*).

THYSANOPTERA.

These insects have four long, narrow, membranous unfolded wings, well fringed with hairs, from which the name of the order is taken. There are few veins. The wings at rest lie horizontally along the back. The mouth-parts are imperfectly fitted for sucking, being intermediate in form between those of the Orthoptera and those of the Hemiptera. The metamorphosis is incomplete.

The name of the order arises from θυσανος, thysanos, fringe, and πτερόν, pteron, a wing. These minute insects are to be found under the bark of trees, in the

[1] Family, *Acrididæ*.

heads of grain, timothy, clover, and in flowers, especially such as the daisy. The majority of this order are plant-feeders; a few are predaceous. These insects, commonly called thrips, are scarcely visible to the naked eye. They are about one-twelfth of an inch long. When the head of a daisy has been rubbed in the hand, a lens will be needed to clearly observe the insects, and even then the observer may require a compound microscope before the fringed wings can be clearly perceived.

FIG. 148. A thrips. Greatly enlarged.

HEMIPTERA.

It is customary among people in general to speak of all insects, or forms resembling them, as bugs. The term can properly be applied only to the members of this order. These have incomplete metamorphosis, haustellate mouth-parts, four wings. The Hemiptera or true bugs include some of our most injurious forms. The term is derived from ἥμι, hemi, half, and πτερόν, pteron, wing. The order contains a number of forms widely diverging from the general type, so that the group is best understood when resolved into two fairly well-defined suborders,— the Heteroptera and the Homoptera. The Heteroptera are those with front wings of an unequal texture, the basal half being the heavier, the outer half not infrequently translucent. It is also characteristic of this suborder that the beak rises from the front part of the head. The Homoptera comprise those with wings of like texture throughout, and beak rising from the ventral portion of the head.

The Heteroptera.—Among the Heteroptera are the chinch-bug, the squash-bug, the box-elder-bug, and the assassin-bug, living on land; and the giant water-bug, the water-strider, and the back-swimmer, living in the water. Those land forms which have been mentioned, with the exception of the assassin-bugs, live upon the juices of plants. The assassin-bugs lie in wait and seize upon other insects, pierce their prey, and draw therefrom the lifeblood. Those living in water are all predaceous.

FIG. 149. Box-elder-bug (*Leptocoris trivittatus*). Enlarged.

Giant Water-Bug.[1]—When electric lights came into general use for street illumination, there frequently appeared around them an unusually large insect. Great numbers of such insects were wont to congregate around the lights, and they soon became known as "electric-light bugs." This insect in reality is one of the aquatic forms of this order. It is predaceous. It darts out from some cranny nook in brook or pond to catch small fish, tadpole, or other aquatic insect. Having secured its prey, this giant water-bug drives in its beak and leisurely regales itself with the

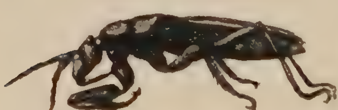


FIG. 150. An assassin-bug (*Melanolestes picipes*), showing strong beak and large fore legs fitted for grasping.

[1]Family, *Belostomidæ*.

blood of its victim. This insect is harmless, but would readily use its beak in self-defense.

The Homoptera includes such forms as the cicada or harvest-fly (sometimes erroneously called locust), the buffalo tree-hopper, aphids or plant-lice, and scale insects. Of all the insects in this order, possibly the plant-lice and scale insects are the most unique in their development.

FIG. 151. Giant water-bug (*Benacus griseus*)—natural size.

The plant-lice, in addition to a very peculiar mode of development, have within their family certain species which secrete a kind of honey much appreciated by certain ants; and as these ants have now come to rely upon this as a means of subsistence, they have in many cases adopted, as it were, the plant-lice, and care for them by moving them about to the tenderest parts of the plants from which the aphids draw their nourishment. And in turn the aphids, from long attention by the

FIG. 152. Cicada and cast-off nymphal covering—natural size. From a photograph.

ants, have become dependent upon the ants. This illustrates the effects of use and disuse. Undoubtedly the aphids were once independent and self-supporting

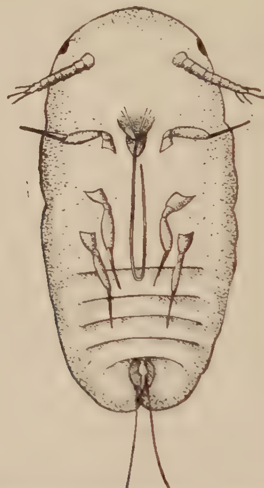


FIG. 153. Newly hatched scale insect. Greatly enlarged.

and unattended by ants. Had the ants never undertaken the care of these aphids in the first place, the aphids would still be in full possession of all their powers and instincts; but the ants having through many generations assumed the care-taking responsibility, this faculty or instinct of the aphids, not being used, has evidently been lost. Ants running up and down trees are not infrequently going to and from these aphid pastures. Among the plant-lice

FIG. 154. Protective covering of female scales (*Aspidiotus greenii*).

we find winged individuals, capable of carrying the species into new localities, and wingless forms whose sole duty is the reproduction of their kind.

Among the most anomalous forms of insect life

FIG. 155. Adult female scale insect (*Kermes nivalis*) living on oak twig, showing a form which does not secrete a protective covering. Enlarged. Photographed from nature.

FIG. 156. An unprotected scale. Adult female scale insect (*Lecanium aurantiacum*) living on osage-orange branch. Enlarged.

are the scale insects. The young either come forth from eggs or are given birth, both sexes at first being alike, resembling mites (Fig. 153), and subsisting upon the juices of plants and trees. As they develop, the males go through complete metamorphosis, and emerge as insects with one pair of wings, but without mouth-parts. The female passes through an incomplete meta-

morphosis. After the first molt she loses her legs, antennæ, and eyes, and remains stationary as a footless

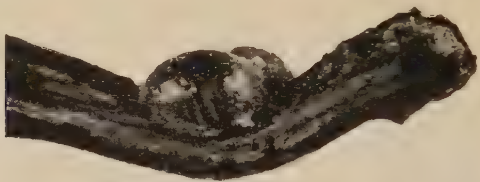


FIG. 157. Adult female scale insect (*Kermes pubescens*) living on oak twig. An unprotected scale. Enlarged. Photographed from nature.

grub upon the host, there to draw sustenance and reproduce her kind. Some female forms of these insects, however, retain the power of locomotion. Many of these footless females are well protected by an outer scale (Fig. 158), which is formed by an excretion from the dorsal part of the body. Others are naked. (Fig. 157.) To the former kind belong the noted and injurious scale commonly known as the San José scale.

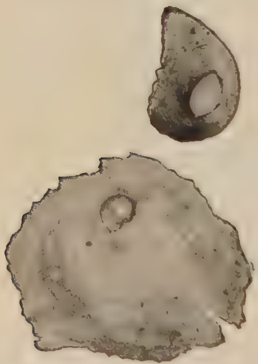


FIG. 158. Protected scale insects. Scales under which female scale insects (*Diaspis snowii*) live. These scales are formed from a waxy substance which is an excretion from the back of the scale insect's body. The scale does not adhere to the insect's back.

FIG. 159. Protected scale insect. Scales which cover the male scale (*Diaspis Snowii*) during its metamorphosis.

FIG. 160. Adult male scale insect (*Aspidiotus ancylus*). Enlarged. Drawn by Miss M. E. Wise.

The true lice, those that live as parasites upon the skin of mammals, belong to the Hemiptera. Some authorities place them in a separate suborder called Parasitica.

COLEOPTERA.

These insects possess well-defined mandibulate mouth-parts. The wing-covers are horny and do not overlap, but meet along the median line of the back. The wings proper, the ones most useful in flight, are delicate, membranous, and are concealed beneath these wing-covers. The metamorphosis is complete. These insects are commonly called beetles,

FIG. 161. A water scavenger (*Hydrophilus triangularis*). × ½.

and include such forms as the June beetle, the lady-bird, the potato beetle, the fireflies or lightning-bugs, and the plum curculio. The Coleoptera are not likely to be mistaken for those of any other order. The term arises from two Greek words, κολέος, coleos, meaning sheath, and πτερόν, pteron, wing.

FIG. 162. A click beetle (*Alaus oculatus*). From photograph. × 1¼.

FIG. 163. Wood-boring beetle at work in yellow-pine board. Photographed from life by W. C. Stevens.

Basing the classification upon the mouth-parts, the order is divided into two groups: the true beetles, such as the June beetle and the ground beetle (page 277),— those with typical mouth-parts; and those with mouth-parts developed into a long snout, such as the plum curculio, and the snout beetle illustrated in the figure. (Fig. 164.) The order embraces a large number of species, and a number of these are of common occurrence. Some forms, such as the tiger beetles, the ground beetles, whirligig beetles (or "lucky

bugs"), are predaceous. Other forms, commonly called borers, are such as the apple-tree borer, the pine-tree borer (Fig. 163), and the cottonwood borer, the larvæ of which live within the trees named. There are likewise forms which feed upon leaves, such as the potato beetle and June beetle. A few abnormal species are parasitic upon bees and wasps. Those whitish grubs found when spading, or when in quest of angleworms, belong to the June-beetle family. The eggs from which they emerge are laid beneath the surface of the ground, to hatch within a month to feed upon tender rootlets, or decayed vegetable matter. In autumn they hibernate below frost line; in May they pupate near the surface; in June they emerge.

FIG 164. A snout beetle (*Sphenophorus ochreus*)—twice natural size.

The familiar ladybird larvæ are for the most part predaceous, feeding upon other insects, especially plant-lice and scale insects; consequently the black or spotted larvæ are to be found running around upon plants and trees. (Fig. 107.) Pupation takes place with the pupæ pending by the abdomen from leaves, fences, or trunks of trees.

LEPIDOPTERA.

These are insects which have long been the recipients of popular attention. They possess haustellate mouth-parts, which take the form of a spirally rolled proboscis, four wings, similar in structure, and covered with minute scales. The metamorphosis is complete. The

larvæ of these insects are commonly called caterpillars. Lepidoptera is composed of two Greek derivatives: λεπίς, lepis, scale, and πτερόν, pteron, wing. These scale-winged insects are divided into moths, skippers, and butterflies, dependent upon habits and structure of the antennæ. (Figs. 167, 169, 170.)

FIG. 166. The "humming-bird" moth (*Phlegethontius celeus*) with proboscis extended, to show its length—about one-half natural size. From a photograph.

Moths.—Nearly all moths are night-flyers. Some fold the wings when at rest, longitudinally and frequently roof-like upon the side of the body; others retain the wings horizontally. Many moths find protection in their color resemblance to objects upon which they rest.

Skippers are so called from their uneven manner of flight; when resting upon some flower or damp spot

—13

on the ground they impress one as extremely nervous beings. The wings keep moving from vertical to horizontal and back again. If there be a momentary rest it is generally with the wings held vertically. Sometimes the front wings are held vertically while the hind wings are resting horizontally. One unacquainted with the manner of flight might suppose the insect to

FIG. 167. Luna moth (*Actias luna*), showing form of moth antennæ. 5/8

be a wounded butterfly, so irregular and spasmodic is their mode of action when on the wing. Their antennæ are also characteristic. (Fig. 169.)

Butterflies are day-flyers, and are more slender in body than either moths or skippers. The wings are generally held vertically when at rest. The antennæ are also distinctly characteristic. (Fig. 170). The life history and the habits of one of these has been illustrated elsewhere. (Pages 13–23.)

FIG. 168 "Pitcher" pupa of "humming-bird" moth. In the larval stage, this insect is to be found as a large green caterpillar on the tomato vines. Natural size. From a photograph.

FIG. 169. A skipper (*Eudamus* [*Thorybes*] *bathyllus*), showing recurved tips of antennæ—natural size.

FIG. 170. Interrogation butterfly (*Grapta interrogationis*), showing form of antennæ in butterflies. (Figs. 38 and 39 illustrate larva and pupa of this butterfly.) From photograph.

DIPTERA.

Insects with haustellate mouth-parts, front wings membranous, hind wings replaced by knobbed processes called halteres. The metamorphosis is complete.

FIG. 171. A fly (*Sarcophaga cimbicis*) and its pupa-case, showing bursting off of end of pupa-case to be its method of emerging. Enlarged.

The name is derived from δις, dis, double, and πτερόν, pteron, wing. The Diptera include all insects which can properly be called flies. Such forms as the house-fly, the mosquito, and the horse-fly are Diptera. While the mouth is fitted for sucking, in some flies such as mosquitoes that organ is fitted for piercing the skin and sucking the blood. The order is a large one, and the species differ much in manner of life. The larvæ are commonly called maggots.

The females generally lay their eggs in the vicinity of the proper food for the maggot. Our common house-fly prefers fresh horse-manure for oviposition. Upon this the maggot feeds about a week, then transforms into the pupal stage, remains so for about another week, and then comes forth as a two-winged insect to find its way inside mosquito-barred doors and windows, or into dwelling-houses not properly guarded.

The method of emergence from the pupal case is of interest. The larvæ of more generalized forms such as the robber-fly, come forth from a straight seam in the side of the case, and in this differ not at all from the mode of many other insects. In the case of the more

specialized forms, such as the house-fly, when they are ready to escape there forms upon the front of the head a sort of balloon, which blows off, as it were, the end of the pupal case, and allows the fly to walk out. Then the bladder-like forehead gradually recedes and the head becomes normal.

FIG. 172. Robber-fly (*Erax cinerascens*) —one and one-half times natural size.

Fleas. — These aberrant insects are by some authorities placed in a separate order; by others in a suborder of the Diptera. They are wingless insects, with body compressed, legs well developed, and adapted for jumping. The female lays about a dozen eggs. These are deposited in the dust accumulated in cracks and crevices. The larvæ have a head and jaws, and feed upon decaying bits of animal and vegetable matter found in the crevices where they live. Their pupal stage is passed within a cocoon spun by the larva. The mouth-parts of the adult are fitted for piercing and sucking. Among domestic animals they are to be found upon the cat, dog, rabbit, poultry, and pigeons. There is a species which lives upon the cat and dog — a flea which at times also proves annoying

FIG. 173. A flea (*Ceratopsyllus serraticeps*). Enlarged ten times.

to man. In Europe there is a species of flea which is very troublesome to man. This species occurs sometimes in this country.

HYMENOPTERA.

These insects have four membranous wings. The hind wings are smaller than the front wings. Mandibulate mouth-parts, in many cases accompanied by

FIG. 174. A wood-boring hymenopteron, the pigeon horn-tail (*Tremex columba*) —natural size. From photograph.

proboscis; metamorphosis complete. The name arises from two Greek words, ὑμήν, hymen, membrane, and πτερόν, pteron, a wing.

This order includes the bees, ants, and wasps, well-known forms, remarkable for their social habits and marvelous instincts. The order may be divided into three groups, divisions based largely upon the habits of the insects.

Plant-eating Hymenoptera are those whose larvæ have feet, and are capable of moving about in quest of food; they somewhat resemble caterpillars. The meta-

morphosis is similar to the metamorphosis of Lepidoptera, except that the pupal case is soft and assumes no hard outer skin. They feed upon plants. Such is the rose slug, that greenish worm with delicate skin, which, feeding mostly at night, skeletonizes the rose-leaves. This work of the slug gives the bush a decidedly fire-burnt appearance. This group is commonly called "saw-flies," because of the two saw-like processes of the ovipositor. The larvæ of some other members of this division bore in wood. The adult insects of this division can readily be distinguished from the two subsequent groups by the broad basal union of the abdomen with the thorax, the caliber of the basal segments of the abdomen being about such as is usual in insects of the same size. The two groups which follow have the abdomen connected to what appears to be the thorax by a slender stalk. On account of this peculiar joining of the two parts of the body we find such terms in use as "thread-waisted wasps."

Parasitic Hymenoptera.— Ichneumon-flies are the chief members of this second division, characterized by the parasitic habits of the larva. These larvæ are usually parasitic within the bodies of plant-eating insects. If a society of caterpillars be watched for a short time, long, slender-bodied insects will be observed darting down among the caterpillars. Frequently after the insect has flown away some caterpillar in the assemblage will be observed squirming and wriggling. It is endeavoring to cast off the egg just deposited upon its back. From this egg there will hatch a footless grub — why footless? — to feed upon the body liquids of the caterpillar. Since the vital portions of the host are not

generally attacked, the caterpillar frequently pupates; and so, in collecting chrysalids, especially lepidopterous ones, for emergence, one or many of these hymenoptera, instead of the form corresponding to the pupal case, may come forth from the case.

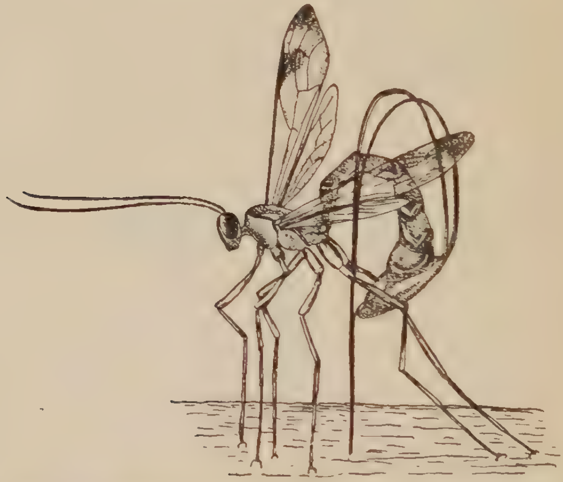


FIG. 175. Parasitic hymenopteron (*Thalessa lunator*) drilling with ovipositor into burrow of the wood-boring larva of the pigeon horn-tail. (After Riley.)

The accompanying figure (Fig. 175) illustrates a parasitic hymenopteron[1] at work. This is one of the larger insects of the order. It is parasitic upon the wood-boring larva of the pigeon horn-tail,[2] another hymenopteron. When Thalessa finds a tree infested by this borer, she selects a place which she supposes to be opposite the larva's burrow, elevates her long ovipositor in a loop over her back, and places the tip of the ovipositor on the bark of the tree. By raising and lowering

[1] *Thalessa lunator.*

[2] *Tremex columba.*

her body she skillfully drills a hole into the tree. When the ovipositor enters the burrow she deposits an egg in it. The larva that hatches from this egg crawls along the burrow until it finds the wood-borer. This wood-borer is a soft-bodied larva. To this the young Thalessa fastens itself, and subsists upon its blood until ready to pupate. It pupates within the burrow of the horn-tail. Sometimes Thalessa is unable to extricate her ovipositor, and is held fast until she dies.

Stinging Hymenoptera.—Among these the female is with few exceptions provided with a sting at the end of the abdomen. Usually the footless — why footless? — larvæ are reared by the females in cells constructed for the purpose. To this group belong ants, bees, and wasps; these have been discussed elsewhere. (See pages 62–88.)

CHAPTER X

GEOGRAPHIC DISTRIBUTION AND THE STRUGGLE FOR LIFE

In the study of physical geography we are accustomed to continental maps illustrating land areas bounded and indented by water areas. In political geography, maps show the divisions and subdivisions of countries based upon artificial conditions. Animal geography is another branch of geographical science, in which maps are of value in defining the boundaries of the areas in which animal forms of definite classes exist normally.

Habitat. — The geographical range of a species of animal or plant is frequently spoken of as the habitat of the species; that is, the region in which the species lives in a state of nature. From this it might be supposed that where the species is originally found there it thrives best, and that there the conditions are ideal for its existence. This is not necessarily so. Of the seventy-three species of insects which occur in the United States in such numbers as to be injurious to man's interests, thirty-seven have undoubtedly been introduced from foreign countries. Less than thirty years ago the eggs of the gypsy moth were imported into Massachusetts from Europe. The insect escaped from confinement. No particular attention was paid to this escape. However, in 1890, some twenty years after the introduction, the State of Massachusetts

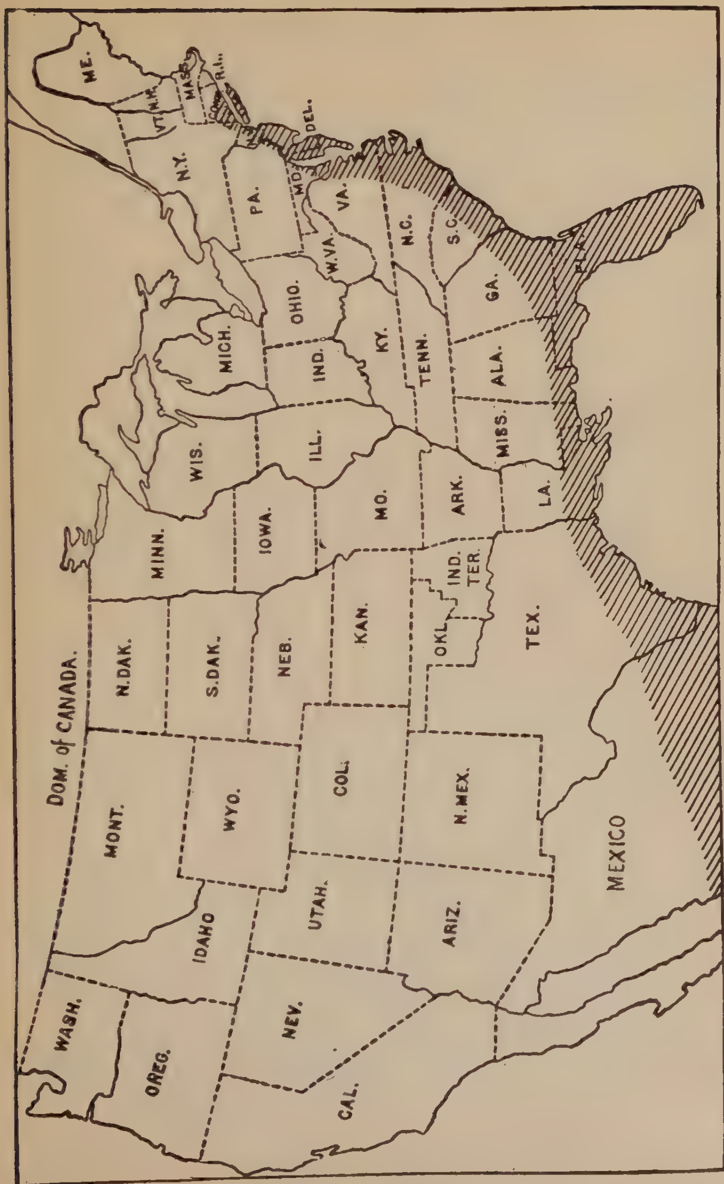


FIG. 176. Map showing habitat of the swallowtailed skipper (*Eudamus proteus*). The butterfly lives in that portion of the country shaded on the map,—a warm, moist region.

found it necessary to appropriate funds for carrying on measures looking toward the permanent reduction of the numbers of this insect. The caterpillars have continued to multiply and defoliate the trees each year. In remedial work against this insect the State of Massachusetts has already spent over half a million dollars, and much more must be spent before a permanent check to its destructive increase can be assured. From these facts it is readily inferred that the boundaries of the habitat of a species are not constant, but are subject to change. Every species unwittingly strives to extend its territory, to gain more room to live, to disturb the balance of forces which holds all in restraint. In this, some species are successful, and extend their domain; others are not; they cannot hold their own; they occupy less and less territory until they become extinct.

Barriers.—Checks to the extension of range differ with different groups of animals. Most mammals cannot traverse oceans, nor can fishes cross continents. Insects, however, have a wide distribution. This group is represented in every part of the globe so far visited by man, from the extreme limits of the Arctic and Antarctic regions to the equator, and from the sea-level to altitudes far above the line of perpetual snow. Humboldt observed insects on Chimborazo at an elevation of 18,000 feet. They exist in fresh and salt waters, in subterranean caves and in hot springs, the waters of which reach moderately high temperatures. A certain small fly (*Psilopa*) has been found breeding in petroleum, a substance formerly supposed to be fatal to insect life. In view of the vast numbers and varied forms of insect life, it is not so surprising that this

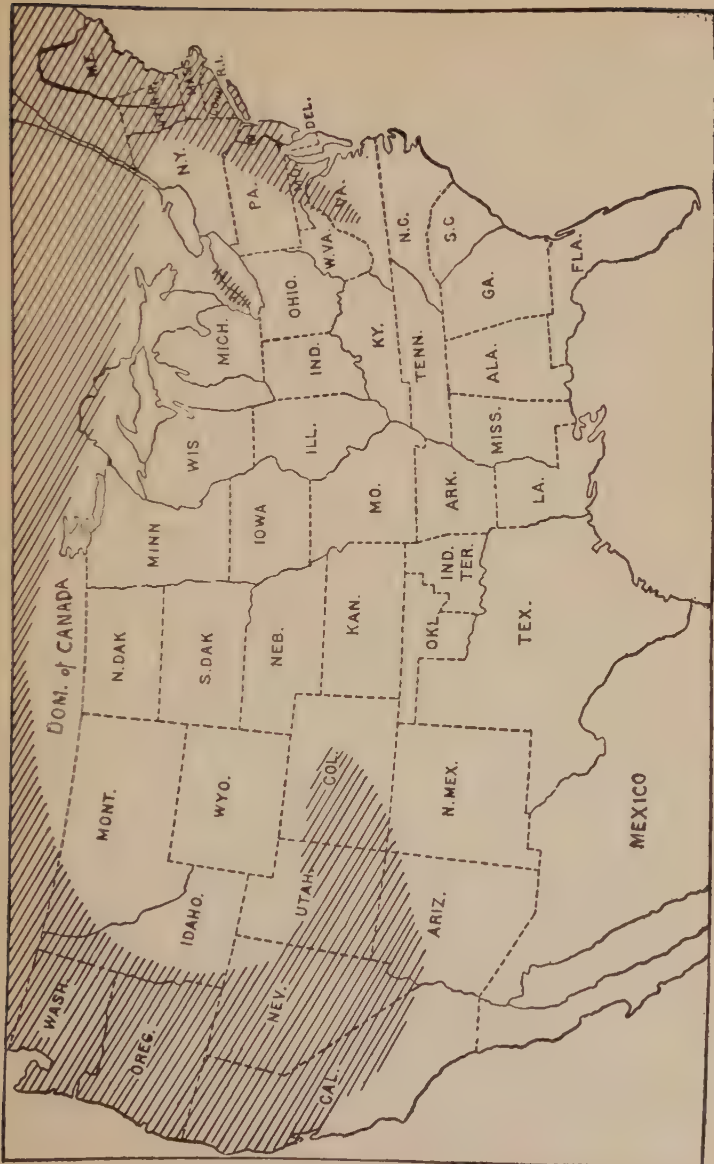


FIG. 177. Map showing habitat of the brown elfin butterfly (*Incisalia augustus*). Butterfly found in region shaded on map. Illustration of an insect not closely confined to one series of climatic conditions.

group exists over such a vast area and under such diverse conditions. What has been said of the group as a whole cannot be said of the individual species in this group. They, in their attempt to extend their range, are subject to barriers. The barriers which restrict the spread of species of insects may be classed under two general divisions: (*a*) barriers which prevent entrance into new territory; (*b*) barriers which prevent maintenance after introduction.

Barriers to Entrance.— Checks, such as oceans, or high mountain ranges, which affect many animal forms, are not always valid in the case of insect species. Insects surmount some of these obstacles through powers of flight, or are transported. While it is not possible for them to carry themselves across oceans or over high mountain ranges, they are frequently transported during quiescent periods such as the egg and pupal stages. The eggs, the pupa, or even the larva, of a wood-boring species, may drift in the heart of a log across an ocean. Through chance, mammals or birds may carry species of insects, during the quiescent stages of insect development, across possible insect barriers into new territories.

Barriers to Existence.— Introduction into new territory does not decide the establishment therein of the insect introduced. Climate is an important element in the life history of an insect. Some insects require a high altitude with its accompanying dry atmosphere and moderate heat. Others can exist only under conditions to be found in low lands with their marshes and humid atmospheres. The collector who studies the same locality for some time will notice that the insects dwelling in marshy meadows differ from those of

the rocky cliff. The Parnassian butterflies, alpine species, seem to require cool climate; consequently they are to be found in northern countries and in the high altitudes of mountainous regions. The clouded skipper butterfly seems to thrive in a warm, moist climate. Its habitat, then, in the United States is restricted to a strip of land along the Atlantic seaboard and the Gulf of Mexico.

While climatic conditions may not be unfavorable, there is still another barrier which in the case of many insects effectually prevents their spread. This is food plants. There are many insects, notably butterflies, which at some stage in their development are dependent upon a certain plant or family of plants for sustenance. The larvæ or caterpillars of many butterflies will thrive only upon certain plants. If these plants are wanting in a new territory, it is evident that there will be no increase in the respective species. The milkweed butterfly, already referred to under other phases, is a case in point. The caterpillar of the milkweed butterfly will grow and develop only when feeding upon the leaves of some member of the milkweed family. This insect belongs properly to the tropics, but has now a widespread distribution. It was unknown in Hawaii until a member of the milkweed family established itself in Hawaii. Similar observations have been made concerning its existence on a number of other oceanic islands subsequent to the natural growth thereon of the milkweed.

Fauna.— The term "fauna" is used to designate the animal life of any district. The fauna of Iowa, for instance, refers to all the animal life in a state of nature

within the borders of the State. The insect fauna of Iowa consists of all the insect life existing within the borders of the State. State lines, however, have no influence in themselves upon the distribution of species, so that the fauna of Iowa and that of the adjoining States of Missouri and Illinois would probably vary but little.

Zones of Life.— The continent of North America may be divided upon the lines of animal and plant distribution into three primary transcontinental regions: Boreal, Austral, and Tropical.

The Boreal region covers the whole of the northern part of the continent, from the polar seas southward to the northern boundary of the United States. A narrow strip along the Pacific coast and the higher portions of the Sierra Cascades, the Rocky Mountains, and the Alleghanies, all in the United States, are in this life zone.

The Austral region covers the whole of the United States except the Boreal mountains and the Tropical lowlands.

The Tropical region covers the southern part of the peninsula of Florida, the greater part of Central America, the lowlands of southern Mexico south of the table-land, and a narrow strip on each side of Mexico. This strip follows the coast northward into the United States.

The fauna and flora — that is, the animal and plant life — within each of these regions are not alike throughout the respective regions. They show striking differences. This has led to the subdivision of these principal zones into a number of minor areas based

upon the particular grouping of plants and animals. Maps are used to show zones of life. In like manner the habitat of each species can be mapped out. (See Figs. 176, 177.)

Modes of Distribution.—Little has been done in the study of the geographic distribution of insects as a class, because many of the groups are liable to be transported by accidental causes, so that there is a tendency to consider their faunal areas quite unstable. Nevertheless, among insects there are many species whose habitat is greatly localized, due in a measure to the extreme narrowness of the life habits of the species; that is, they have become so adapted to a certain food plant, certain climatic conditions, and to association with certain other forms of animal life, that they cannot exist away from these set conditions. In the study of insect distribution, all these factors and conditions are to be considered.

The manner in which insects can be distributed in a state of nature are: over landed areas, by flight or travel, winds, transportation on birds, mammals or other animals; across seas to new lands, by flight, (insects have been met in flight three hundred miles from mainland,) transportation in egg, larval or adult stages, on driftwood. Commercial activities, instituted by man, greatly facilitate the spread of insects. In the first place, insects can be introduced intentionally, as in the case of the gypsy moth. They can likewise be, and more frequently are, accidentally transported. The frequency of commercial exchanges between maritime powers, as well as the rapidity of the journey,

FIG. 178. Map of United States, showing principal zones of life.

greatly increases the possibilities of such means of transoceanic extension of species. Continental commerce will likewise facilitate the spread of insects across continents. Insects which enter the hold of a lading ship can exist through a reasonable sea voyage. Their establishment in the new country depends upon the finding of suitable food, and the number and sex of the individuals of the species transported. It is possible that in the merchandise or the packing surrounding merchandise the majority of successful transportations are made. Especially is this true in the case of scale insects, since nursery stock furnishes not only means of transportation, but at the same time sustenance. The female scale, of limited powers of locomotion, has in a state of nature limited distribution. Under present commercial conditions the spread of these insects has been unusually great. The San José scale was known in this country in 1888 in California only. Through commercial traffic it now exists in more than thirty States of the Union.

Deductions. — In this study of distribution, light is thrown upon the subject of land relationships. It is fair to suppose that an island fauna, similar to the adjoining mainland, and whose similarity cannot be accounted for on the ground of transportation, can be accounted for on the ground of a previous land connection of the island with the mainland. If the fauna of an island differs materially from that of the nearest mainland, this seems to indicate a separation of great antiquity, or possibly a distinct separation of the two land areas from the beginning. The fauna of Madagascar, for instance, differs widely from the op-

posing mainland of Africa. This is due, it is believed, to the fact that Madagascar has been separated by water from the mainland since remote times. This belief is strengthened by the notable depth of Mozambique channel. From studies of this nature, together with geologic data, islands can be divided into two classes: continental, those once a part of the mainland, and oceanic, those which have never been connected with any one of the continents.

A study of the modes and possibilities of transportation and introduction of insect life is further profitable in determining the desirability of the entrance of species injurious to the interests of man. And if such inimical forms are introduced, it may be possible to determine the original habitat of the inimical forms and to seek their natural enemies. The question, then, becomes: Can these insects be safely introduced to prey upon the injurious insect? As an illustration: The fluted scale some years ago promised fair to greatly curtail and possibly destroy the citrus trees of California. It was found after investigation that this scale was of Australian origin, and that in its native habitat a ladybird beetle, both in larval and adult state, preyed upon this scale. This beetle was successfully introduced into California, where it has curtailed the increase of the scale and consequently its damage to the citrus industries.

The Struggle for Life.—The progeny of a single fertile female San José scale insect for a single season, not reckoning mishaps, is over three billion individuals. The queen of the honey-bee hive during the working season deposits from two to three thousand eggs daily.

Five hundred eggs would be a small average for females of the insect tribe. If all of these eggs were to bring forth individuals and all these individuals and their progeny were to continue the reproductive process, how long would there be sustenance for such myriads? It has been estimated that if the eggs of a common house-fly should develop and each of its progeny should find the necessary condition for growth and development, without loss or destruction, the people of the city in which this might happen could not get away soon enough to escape suffocation from an atmosphere filled with flies. Such conditions do not exist. Why not? Are there certain persons detailed from each community to prevent undue multiplication? Evidently not. If all these forms were to appear the food supply would soon be exhausted. The facts are that the percentage of eggs which develop into mature forms is very small. Unusually favorable conditions sometimes occur to permit a goodly percentage of the eggs to hatch and attain maturity. At such times we have plagues. The multitudes of maple-worms and grasshoppers which sometimes appear are illustrations. But these are not of regular occurrence. Since, then, all insects do not reach maturity, what determines which ones shall succumb and which ones shall live? "All live who can." It is evident that there must be strife for existence; that among insect forms as well as higher animal forms there is a struggle for existence,— a struggle which for the greater part is unconsciously carried on by the individuals concerned. Some are destroyed by mere accidents. Aside from this the struggle takes place: (*a*) Between individuals of

the same kind, contending for necessities of life, as grasshopper and grasshopper; a "struggle between fellows." (*b*) Between insects of different kinds, the one endeavoring to devour the other, as grasshopper with parasitic fly or predaceous beetle; a "struggle between foes." (*c*) Between insects and conditions of life, as the grasshopper and the unfavorable winter climate or the chance of securing proper nourishment in the early spring; a "struggle with fate."

Fig. 179. Long-winged grasshopper of the plains (*Dissosteira longipennis*). In 1873 the female of this species was unknown to scientists. The knowledge of the existence of such an insect was based upon the finding of a male. From a photograph.

To those who live there must be accredited some characteristics not possessed by those who perish. If such a characteristic protects or favors the life of the individual, this characteristic will tend to remove the individual from the intensity of the struggle. Traits of advantage which have been evidenced during this struggle are the "protective devices" discussed in Chapter IV, and chief among the others are: warning colors, parasitism, social organization, feigning death.

Warning Colors.— The object of protective coloration is to conceal or disguise. The purpose of warning colors

FIG. 180. Front of a store building in a Colorado town, showing great numbers of the long-winged grasshoppers of the plains. Myriads of these grasshoppers flew into this city, so that for two nights it was deemed advisable to do without the electric lights in order not to attract the flight of these insects. Street-cleaning forces, with wagons, were employed to clear the streets of the hordes of insects. This occurred the last few days of July, 1898, and goes to illustrate the rapid rise or increase of a species.

is the very opposite, the retention of such coloration being to render as conspicuous as possible the form wearing them. Some of the most striking illustrations of warning colors are to be found among insects. The young collector will soon be able to divide insects into two general classes,—those difficult to distinguish from their surroundings, and those quite conspicuous. The protection does not lie in the colors in these cases, but in some unpleasant attribute connected with insects wearing such colors. Many hymenoptera, for instance, possess stings. Stinging insects, we find, are rendered conspicuous by warning colors such as the contrasted dark and yellow bands of the common wasp, the hornet, and of many bumblebees. The red and black ladybirds are quite conspicuous. These have been shown to be extremely nauseous to insectivorous animals. Some white moths and some moths made conspicuous by their white and black colors have been refused in disgust by insect-eating animals. Many caterpillars with the ability to emit noxious juices are rendered conspicuous either by striking colors or exposed positions upon their food plants.

Parasitism.— Hunger and the quest for shelter have doubtless led to the habit of existing as unbidden guests in or on plants, other insects, or higher animals. The one, a parasite, lives in or on the other, a host, securing the necessities of life from the host. The host gives up a part or all of its vital force to the parasite. Very few species of insects are exempt from the entertainment of parasites. Parasites themselves are parasitized. Among insects are to be found all variations of para-

sitism: the external parasite, as the sheep-tick, or the bird-louse, external parasites spending the whole existence upon the host; the ichneumon-fly, depositing its eggs upon the back of some caterpillar wherein the ichneumon larvæ will dwell until pupation, then to emerge as a winged insect, an internal parasite for part of its existence. The advantages gained by the parasite are great,—abundant food, safety, and warmth, all necessities of its natural well-being. There are, however, disadvantages. The parasite tends to degenerate through disuse of organs. The sheep-tick was once a winged fly, but since it spends its whole life upon the same animal its wings were no longer used, and consequently were less and less developed. The female scale insect after settling upon plants becomes simply a living sac, a footless, headless grub, capable of digestion and reproduction. Parasitic insects that depend exclusively upon certain forms for existence lay themselves liable to great reduction in numbers, even to extinction. This is likely to occur should their host become greatly reduced in numbers, either through the attacks of the parasites themselves, or through other causes.

Chief among parasitic insects are the Hymenoptera. These prey largely upon vegetable-feeding insects, by dwelling as footless grubs in the bodies of the hosts, subsisting upon the so-called blood of the insect.

Among Hymenoptera there are some parasitic upon plants, and others are parasitic upon eggs of other insects. This subject of insect parasitism is of so great biologic importance as to be of vital interest to man

himself. Insects primarily depend upon vegetation for sustenance. So rapid are their powers of assimilation and so prodigious their efficiency for multiplication, that, were they to go on unheeded and unchecked, they would in the struggle for existence overcome mammals.

FIG. 181. Cecropia larva bearing cocoons of a parasitic insect, an ichneumon fly. ⅝.

Such is not the case, however. Insects are as a house divided, one part preying upon and destroying the other; the two succeed each other like wave upon wave. Parasites, finding innumerable insects to prey upon, increase so rapidly as to devour their means of support. They in turn succumb and the host rallies, only to be again defeated. So the struggle goes on forever.

Parasites do not confine themselves to forms gaining an independent livelihood, but attack those of like habits as themselves — a phenomenon usually termed hyper-parasitism. Not only do parasites attack parasites, but cases of secondary parasitism are numerous, tertiary parasitism is not rare, and quaternary parasitism has been suggested as possible. Insect parasitism is of wide prevalence. A few years since the trees of the city of Washington, D. C., were almost wholly defoliated by the white-marked tussock-moth. The great numbers of bodies of these insects attracted and furnished food for parasites, until in the second season ninety-seven per cent. of the caterpillars were destroyed

by parasitic insects. This is only one of the many recorded instances.

Social Organization.—We have already observed that insects qualified to conduct their affairs in colonies and societies are eminently successful. This congregating together is not confined to adults. Certain caterpillars possessing the property of emitting nauseous odors are gregarious. The meaning of this habit seems evident: when many individuals emit this offensive odor at the same time, they become enveloped in an atmosphere which effectively serves to repel attack.

Feigning Death.— Motionless objects attract notice less readily than moving objects. Upon the slightest disturbance some insects and many caterpillars become inactive, and for a time remain motionless. In the case of the attack of another insect with motives of conquest rather than an appetite to satisfy, this inactivity may allay further antagonism.

How can we account for the evolution or development of these various traits? We have observed that no two individuals are identical, and that variation in structure and habits exists. Under "Artificial Selection" our attention is called to the fact that under the intelligent selection of man these variations can be perpetuated and become more marked. It remains for us to see if some such selection of forms can be found in nature, a selection which by unions strengthens propitious variations or traits.

Artificial Selection.— The character of our domestic animals is largely due to the intelligent selection exercised by man. We have the sagacious shepherd dog, the bloodhound with wonderful keenness of scent, the

greyhound with weak powers of scent but keen-eyed and fleet-footed. All these have been evolved, under man's direction, from the progeny of the wolf. By artificial selection the many varieties of pigeons, such as the fantail, carriers, and pouters, have been produced from the wild dove of Europe. Every stock-breeder and poultry-fancier is familiar with these principles of artificial selection. Those animals or birds which possess the desired qualities in the highest degree are retained for breeding, while the rougher, smaller and less desirable stock is marketed. Artificial selection may do in a few generations what natural selection would do eventually.

Natural Selection.— Let us see if it is possible to find similar selection in the natural course of animal life. We have seen that but a small percentage of insect life reaches maturity, due to the struggle for existence throughout nature. Those who do survive do so by reason of some individual peculiarities. These peculiarities seem to be favorable. These favorable peculiarities, characteristic of the survivors, are transmitted to their offspring. Since both parents are liable to possess these peculiarities, the offspring are liable to show the peculiarity in a more marked degree. And so it will continue with subsequent generations. Those with favorable variations or peculiarities are liable to live to perpetuate these traits; these traits tend to become more marked with each generation. The tendency is for those having these favorable traits in a small degree to succumb without leaving progeny. The weaker wasp in its endeavors to capture a spider as provision for its young is more liable to succumb than the stronger.

The more nauseous the caterpillars are to insect-eating animals, the less likely are they to be molested. Thus, Nature is herself making selections. The tendency of this struggle and of this selection by nature is to retain an equilibrium, a balance of forces. Under conditions that remain unchanged from year to year and century to century, it is possible for species to adapt their habits and instincts to their surroundings. But under changing conditions, such as we know have taken place in climatic conditions and in land and water areas, species must adapt themselves, must become modified to these altered conditions, or cease to exist. The tendencies of this selection brought about by the struggle of life seem to be to bring to perfection all forms engaged in the struggle.

PART II

METHODS AND APPARATUS.—STRUCTURE AND CLASSIFICATION OF INSECTS

CHAPTER I

ACQUISITION AND PRESERVATION OF INSECT FORMS

If there is one thing above another which commends the study of insect life in the secondary schools, it is the comparative ease with which the biological material can be procured. The study of Zoölogy is essentially a study of things, not books. And these things must be in the student's hands. Books furnish suggestions for study; they call attention to points liable to be overlooked by the untrained eye. In order that the practical as well as the highest educational value can be attained, the forms must unquestionably be placed in the hands of the student.

The teacher, situated far inland, who places stress and long study upon marine forms, unless well supplied with material, overlooks the most important element in Natural History instruction. The student needs to know not only the component parts of the form under consideration, but the reasons for the existence of these conditions. True, he may be told them. This makes little impression. With how much more force will the lesson come to him if he is enabled to see with his own eyes that the colors of the grasshopper harmonize with its natural surroundings; that the cloak of the pupa has a capacity to resemble in color its support; that

the pronuba moth does collect the yucca pollen and place it in the stigmatic chamber, and that it has organs, belonging to no other insect of the order, peculiarly developed for the purpose,— than if he reads or is simply told that some of the organs of fishes which dwell at great depths in the sea, being adapted to sustaining great pressure, burst when brought to the surface-water; that the angler, which dwells at great depths, bears on the tip of the dorsal spine overhanging its head a phosphorescent light that attracts small fish, upon which the angler feeds.

MATERIALS FOR FIELD COLLECTING.

The inland teacher has a wealth of material right at hand, easily obtained and as easily prepared. The tools required for collecting are: a net, cyanide bottle, vials for preserving, alcohol 70%, formalin solution 2%.

How to Make a Net. — The frame of the net is made of a circle of wire, in size about No. 8. The circle is twelve inches in diameter; the ends of the wire circle are bent out, and are then soldered into a thin thimble five inches long. This part of the net had best be made by a tinner, and the cost of the same should be but a few cents. An empty fifty-pound flour-sack, thoroughly washed and bleached to remove the starch, may then be fastened to this rim. The rim of the net coming in contact with bushes wears out quickly, and therefore a binding of heavy material is placed there to give extra durability to the net. The thimble should not be over an inch in diameter. Fit into the end of this thimble a broom-stick about three feet long, and the net is ready for use.

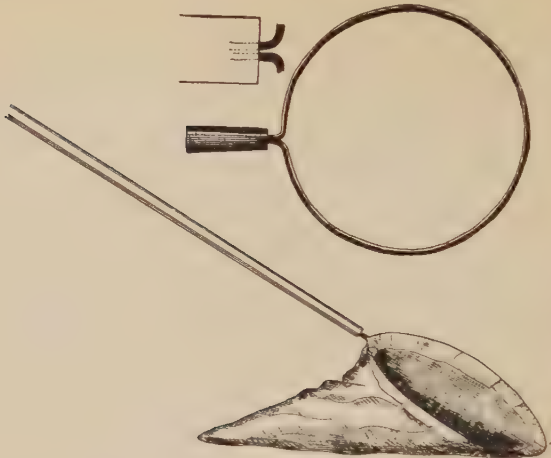


FIG. 182. Net and hoop.

Another Way to Make a Net.— The bag of the net may be made of almost any light-weight material; cheese-cloth, mosquito netting or bobbinet are among the materials used. For nets to be used both in capturing insects

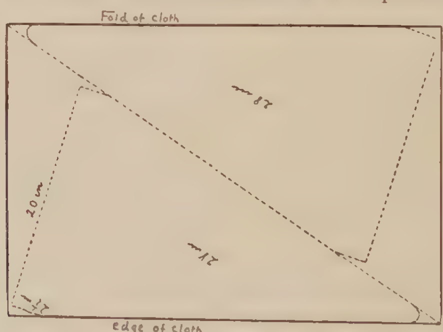


FIG. 183.

on the wing and for sweeping the grass, a firm quality of cheese-cloth answers very well. The cloth should be as wide as the circumference of the wire hoop. The

hoop is first wound with a narrow strip of the goods, to prevent the wire from wearing on the cloth. The bag should be two-and-a-quarter times as deep as the diameter of the hoop.

Two bags may be cut from one width of cloth, if properly managed. The cloth is folded lengthwise; the dotted lines in the accompanying figure show how to cut the net. The seams are then sewed up, and the wide upper part folded over the hoop and stitched down. It is necessary to make the upper part of the same width, in order to prevent its drawing in and decreasing the diameter of the opening; so we have shown in the figure a straight cut of two and one-half inches at the mouth of the net.

It is well to protect the covering of the hoop by a strip of heavy muslin sewed over it, since the rubbing of leaves and stems soon wears out the cloth around the wire.

Preserving Materials.—Insects can be preserved in two ways: by placing on pins, or in preserving-fluid, depending upon the character of the insect or the purposes to which it is to be put. If the insect is of delicate texture, such as a larva or a nymph, it will shrivel if pinned. Such should be placed in 70% of alcohol or in a two-per-cent. solution of formalin. Insects collected for the purpose of dissection should be similarly treated, since the tissues remain soft and are easily worked. In the case of insects for immediate use in dissection, these can be killed in 10% solution of chloral hydrate.

A cigar-box, the bottom being lined with corn or elder

pith, or cork, a strap fastened around three sides, then long enough to go over the shoulder, should be taken on every collecting trip. Several sizes of pins should be taken in separate vials, a killing-fluid, such as chloroform or gasoline, in another bottle. Then, when such insects as butterflies, which would be destroyed by rubbing among other insects in the cyanide bottle, are taken, these can be killed while still in the net by pouring a little of the killing-fluid over them. In this way they can be removed from the net without danger of escape. The proper-sized pin can be placed through the thorax and the insect pinned in the cigar-box, to be removed and spread upon return to the laboratory. With these simple and easily procured equipments, added to a pair of keen eyes, we are ready for the acquisition of material for our field study.

Field Collecting.— Many devices are used to lure and trap insects. Brief mention only will be made of such devices, since the student will gain his greatest knowledge of the habits of insects by collecting them in their native haunts. The careful student can soon learn to know for himself where certain classes of insect life abound; what life is confined to the forest, to the orchard, the meadow, and the open pasture; what classes live in the running streams and what ones live in the quiet pools.

The foregoing chapters have had something to say about the habitat of certain prominent insects. It is taken for granted that the first collecting will be for land collecting. The grass contains many forms which live near the ground. By sweeping the net back and forth in front of you, many of these will be captured.

Tree and bush life, insects which live upon foliage, can be procured in the same way by sweeping the leaves of the trees and shrubs. Rocks, logs, and piles of leaves are the habitations of certain forms. Overturn such abodes of insects and see what ones live there.

Young collectors are apt to overlook certain forms to which great importance must be attached. Galls in weeds, upon leaves, and twigs of trees are readily observed and easily taken. Every one who has carefully observed the golden-rod stalk in the early spring is aware of spherical enlargements upon the stalk. Collect a number of these in the early spring, place them under a glass tumbler, and watch them from day to day. You will soon have ascertained the cause of the swelling. Then, caterpillars must not be overlooked. They represent developing life. The changes taking place in such forms are fraught with interest. Place some of each species in alcohol or formalin, and bring the others to the laboratory to be reared. Water life teems with interesting forms. In ponds and sluggish streams, where vegetation fringes the shores, with a common garden rake immature insects and indeed some fully developed insects can be brought to shore.

Note-Book.— Many insects spend much of their lives skimming over the water, and others live upon the vegetation growing out of the water. And so, in collecting, the acquisition of materials is but one of the considerations. The blank book for field-notes should be a record of every insect taken. The geographic location should be noted.

The notes upon insects taken should give the day and year, time of day, kind of day,— hot or cold, clear or

cloudy. The weather influences insect life very perceptibly. The character of the insect's surroundings — that is, taken under stones or logs, or feeding upon certain plants — is also of importance. When insects are found on plants or trees, an opportunity is afforded the student to acquaint himself further with the flora of his vicinity.

This point of the food plants of insects is a very important one, especially in the collection of scale insects and plant-lice.

Map of the Vicinity.— Every student should be provided with a map of the vicinity of his school. This map should show the section lines, all streams of any importance, ranges of hills, and places of historic interest. An idea of the scope of such a map is shown in the illustration. By referring to this the student can trace his various collecting trips and locate the exact position of his captures.

Manner of Keeping Records.—What is the most convenient way to keep these notes? Simply place on the pin beneath the insect a very small card bearing a number, which might be called the accession number; that is, the specimen can be numbered beginning with *1*, and going on,— no two insects bearing the same number, unless they happen to be of the same species, taken at the same time and under like conditions. A corresponding number is entered in the field-book, and opposite this number are recorded the notes and observations upon the insect. Remarks may be added upon the habits of the insect observed; whether active or sluggish; resemblances to the surroundings; attempts at defense; and other points which suggest themselves

FIG. 184. Map of collecting vicinity. An aid in note-taking.

at the time of note-taking. These notes should be written in the field while the collecting is going on. Observations should always be written at the time they are made.

Collecting at Lights.— Insects can be collected at electric lights; but in the collecting nothing more is accomplished than the acquisition of the things, and the knowledge that such insects are attracted to lights.

"Sugaring."— Many moths and some other insects are to be brought to notice by a process termed "sugaring." This consists of placing, before dark, on trunks of trees, fences and similar objects, a paste of sugar and water. Dark-brown sugar is preferable. The paste should be of proper consistency to apply with a brush, but not so thin that it will flow from the object to which it is applied. Cover a space about three inches wide and several inches long on the trees and fence-posts. Do this about sunset. Return after dark with a common lantern in hand, and take such insects as are found feeding upon this sugar paste, by placing the cyanide bottle over each one. Since there may be many insects at the sugar, it is well to be provided with a number of wide-mouthed cyanide bottles. By this method of sugaring some species of moths can be taken, species which are rarely seen under any other condition.

Preservation of Insects.— For reasons already given, those insects which are to be placed in preserving-fluids will need no other attention, unless the fluids become discolored,— then a change of fluid is necessary. A small card bearing the lot number, the writing being made with carbon pencil, should be placed in the bottle with the specimen. Labels pasted on the outside fre-

quently become detached. Remember, that specimens without adequate data, such as covered in the points mentioned, are practically worthless for cabinet use.

Insect-pins are a kind of pins made especially for the purpose. The kinds much used are Klaeger numbers 2, 3, 4, 5, length $1\frac{3}{8}$, and Carlsbader numbers 2, 3, 4, 5, length $1\frac{1}{2}$ inches. These pins are numbered according to their fineness from 00 (the finest in the trade) to 10 (the coarsest). The finer pins are difficult to handle. It will be more convenient for the beginner to mount small insects on points or angles to be described later.

Upon returning from a collecting trip, the insects should be removed from the cyanide bottles, provided all have been at least one-half hour therein. From cyanide bottles place upon dry blotting-paper, and remove all foreign particles with a soft, dry brush. All specimens should be mounted before they become dry and brittle.

Insects should be pinned through the middle of the thorax (mesothorax) when this, as is generally the case, is well developed. Coleoptera, however, should be pinned through the right wing-cover, since if the pin is passed down between the wing-covers these will spread apart. Hemiptera should be pinned down through the triangular piece behind the thorax. This piece is called the scutel.

The pin should always project about one-half inch above the insect, to facilitate handling. To insure evenness in this regard, a small piece of cork inserted one-half inch in a piece of small glass tubing can be used as a gauge. This can be passed over the head of

the pin, and the pin or insect, as the case may be, pushed down until the length of the pin above the body of the insect equals the distance the cork is inserted in the glass tube. Small insects can be pinned by placing on cork or pith and held between fingers or forceps. Insects too small to be mounted in this way can be gummed with any good quality of glue to card-points previously placed the proper distance upon pins. These points can be cut with a pair of scissors, from cardboard. Clip diagonally across a strip about a half-inch wide, placing the scissors about one-eighth of an inch from the end of the strip. Do not make the tip pointed, but blunt. The next cut, made straight across the strip, will give the second cardboard triangle, and so on. Place pins through the wide end of the card triangle, a little glue at the apex. Place the insect on across the tip of the card. The glass tube-gauge can be used to locate properly the distance of the card from the top of the pin. Small flies and small lepidoptera are best mounted on fine pin-points located in small oblong pieces of cork or pith. This oblong piece, like the card triangle, is supported at the proper distance from the head of an insect-pin of suitable size. Insects with long bodies, such as dragon-flies and walking-sticks, sometimes require a narrow strip of cardboard pinned beneath them, or a fine wire passed through the body, as

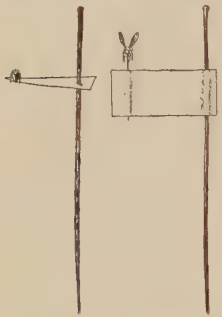


FIG. 185. *a*, insect glued on card-point; *b*, insect mounted on fine pin-point.

a support for the long abdomen. Insects when pinned should be put in a safe place to dry, where they are not liable to be broken and where mice cannot get at them; for mice consider insects, even dry ones, tidbits.

Lepidoptera, and other insects with broad and flattened wings, should have their wings spread. This can be accomplished with the aid of a spreading-board. This board is made of two pieces of thin pine boards laid parallel and fastened by braces at the ends, and if the boards are long there should be a center brace. There should be enough space between the boards to admit the bodies of the insects to be spread. This space

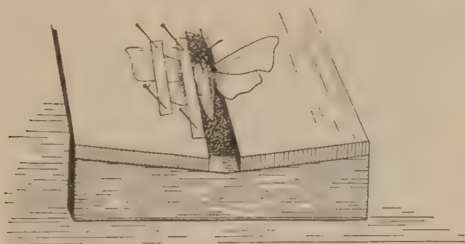


FIG. 186. Spreading-board for Lepidoptera.

between the boards should be covered from beneath with sheet cork or corn pith, to hold the pin upon which the insect to be spread is mounted. The braces should be high enough to allow the pins holding the insect to pass through without touching the supporting-table. To spread the insect, first pin through the mesothorax, then place firmly in spreading-board, by the pin passing through the cork or pith. Pin with common domestic pins a narrow strip of paper across the base of the wings, the pins being fastened a little in advance and be-

hind the wing-margins. Use one of the dissecting-needles (page 252) to move the wings forward into position. This needle should be placed behind one of the strong nerves of the wing, to prevent tearing the membrane. When the wings are in proper position, tighten the basal strips and place another (somewhat wider) strip across the outer half of each of the wings. Fasten with domestic pins in the same manner as the basal strip was fastened.

Cabinets.— Insect-cases are of many devices. Each is suited to its purpose. The high-school collection should be placed in a cabinet that has been erected for the purpose, one that will insure the safety of the collections, and one easy of access for reference and study.

One of the prerequisites of a museum case is, that it be so constructed as to make it practically impossible for museum pests, other insects which live upon dried insects and other museum collections, to gain entrance. Chief among these pests are the little beetles of the buffalo-moth family. Frames can be made of soft-pine strips, one-half inch thick, to fit within the case. These frames are covered above and below with a heavy quality of good white paper, pasted to the strips. This paper frame is dropped within the case, and serves to hold the insect-pins in place. The insects can be arranged in rows, with labels on the left of each series. Four specimens of a kind constitute a series.

A handy case is one the size of which is in inches 10x14x5 (outside measurement). This case consists of two parts of equal size, each being 2½ inches deep. The corners are dovetailed. On the inside of one of the compartments a strip extends from the bottom on each side

up above the box itself about three-quarters of an inch. This is to insure a closed joint when the box is closed. The compartments are fastened together on one side with suitable hinges, and on the other, when closed, with a hook.

The wood in this case should be of some non-resinous kind. Cardboard pasted on light wooden frames made

FIG. 187. A student's cabinet.

to lie within the case fastened in the bottom of each compartment will serve as a receptacle for the pins of mounted insects. For this case, boards one-half inch thick are the proper size. This student case will hold insects in each half, and can be placed on a shelf, upright, in a position similar to a book on a shelf.

Arrangement of Insects.— It will be found convenient to fill all cases with insects of the same order. Within the order arrange the specimens under suborders, families, genera, and species. For the arrangement and

study of insects, several sheets of cork or large blocks to which a layer of corn pith has been glued will prove valuable. These will hold the specimens while being mounted, transferred, or studied.

Relaxing Insects.— Frequently it is desired to spread or pin insects which are rigid. These can be relaxed. A vessel half filled with sand saturated with water, then closely covered, will furnish a moist chamber. In this upon heavy blotting-paper place the insects to be relaxed. Allow to remain from one to three days. They must not remain too long, else mold will destroy them. A few drops of carbolic acid will retard the growth of mold. When the insects have become relaxed they can be handled as readily as when captured.

Mailing Insects.— Students, too, will frequently find it desirable to mail insects in exchange for others, or in order to secure proper identification. This is frequently done. Many exchanges are conducted by mail, and many insects are sent to proper authorities for determination. Pinned insects must be firmly pinned in a box having a sheet of cork securely fastened to the bottom. The box must be tightly covered and wrapped loosely, first with cotton and then with excelsior. A heavy paper should cover all. The excelsior and cotton are to modify the jars and shocks which the package will receive in transit. Specimens in preserving-fluid can be mailed in a regular mailing-case made for the purpose. A cylindrical piece of soft wood can be bored out to accommodate a fair-sized vial well wrapped in cotton. This closed with cork of required size, serves the purpose very well.

Various means and devices will occur to the ingen-

ious student in his studies, and such when perfected will be valuable.

Dealers in entomological supplies, from which such as forceps, pins, sheet cork, etc., can be obtained:

The Bausch & Lomb Optical Company, 513-543 N. St. Paul street, Rochester, N. Y.

John Akhurst, 78 Ashland Place, Brooklyn, N. Y.

M. Abbott Frazar, 93 Sudbury street, Boston, Mass.

Entomological Society of Ontario, Victoria Hall, London, Ontario.

Queen & Co., 1010 Chestnut street, Philadelphia, Pa.

Charles C. Riedy, 532 Montgomery street, San Francisco, Calif.

Dealers in optical instruments, from whom lenses, microscopes, etc., can be obtained:

The Bausch & Lomb Optical Company, New York and Rochester, N. Y.

Eimer & Amend, 205-211 Third avenue, New York city.

Queen & Co., 1010 Chestnut street, Philadelphia, Pa.

The Franklin Educational Company, Harcourt street, Boston, Mass.

William Krafft, 411 W. Fifty-ninth street, New York city.

Spencer Lens Company, 546 Main street, Buffalo, N. Y.

REFERENCE BOOK.

Directions for Collecting and Preserving Insects, C. V. Riley. Smithsonian Institution, Washington, D. C., 1892. Price, 25 cents.

CHAPTER II

INCOMPLETE METAMORPHOSIS

THE GRASSHOPPER

The materials required for the study of the development and habits of the grasshopper are simple and within the possibilities of anyone: a breeding-cage, a pair of sharp eyes, a hand-lens, and an insect net.

The breeding-cage can be very simply made by covering with wire netting an open space left on each side of a good-sized store-box, and placing a quantity of sand in the bottom of the box. This should be placed where a moderate amount of sunlight will reach it during a part of the day. Young grasshoppers are the ones to be desired, and these can be recognized by the absence of wings, and the presence of wing-pads instead. In the very first stages of the grasshopper's life even these wing-pads are absent. Many of these young grasshoppers may be taken without the aid of a net.

A net will facilitate the work greatly, and will also be required in other branches of the study. (See page 224 for directions for making net.)

A good hand-lens can be procured from the jeweler or from some optical firm. (See page 237 for addresses of firms.) Of the lenses more moderate in price, the one known as the Coddington is the best. In buying a lens it will be well to purchase one that will work upon the home-made dissecting microscope described on page 251.

Acquisition of Material.— The breeding-cage well made, equipped and in position, the hand-lens and net as accompaniments for your bright eyes, you are ready to seek young grasshoppers along the roadside, or in the meadows or cultivated fields. Young grasshoppers may be found at any time of the year, but are most common in the early spring. They can be best taken in growing vegetation, such as meadows and pasture-lands, by sweeping, and along the roadsides by dropping the net over them. As a means for carrying them from the field to your breeding-cage a pasteboard shoe-box with a V-shaped trap-door cut in the lid is a handy appliance. It is simple, and a very effective means of transportation. When the grasshopper is caught, the apex of the trap-door is pushed down with the finger and the insect dropped in. The pasteboard has enough spring in itself to close the opening.

Care of Breeding-Cages.— Grasshoppers are not at all delicate in their tastes, and will adapt themselves greatly to existing circumstances. They prefer, however, the cultivated grasses, cereals, and clover. They also eat readily the leaves of young shoots of peach trees. A number of weeds which grow upon cultivated land are also readily partaken of by these insects; the petals of the opening flowers of the common sunflower are not objected to as a diet by some species of grasshopper.

Great care and attention should be given to the breeding-cage, and all dry vegetation and grass should be removed daily. It is well, however, to keep in the cage all the time a few long stalks of weeds or other vegeta-

tion, for the nymphs to ascend and cling to while molting.

Some Points for Observation.— The time of appearance of wing-pads; the time of day when the molt takes place; the color-markings of the insect before molting and after molting; the number of molts; date of maturity; relative positions of the narrow wing-pad and the wide wing-pad in the nymph, and of the narrow wings (the tegmina) and of the wings in the adult; time, manner and place of oviposition. As the work develops the student will find many other interesting facts to increase the volume of his notes.

THE DRAGON-FLY

The study of the development and growth of the grasshopper familiarizes us with the incomplete metamorphosis of an insect which passes its whole life on land. Many insects spend a part of their existence in the water. The dragon-flies are insects with incomplete metamorphosis.

To rear these insects is not a difficult task. In the rearing many delightful as well as instructive observations will be made. The first thing to do is to obtain the insects. Each group of dragon-flies has its own peculiar place. The nymphs — and it is these we will seek to find — of one division (*Gomphinæ*) live in the sediment at the bottom of pools, frequently pools with little or no vegetation on the bottom. Two other divisions (*Agrioninæ* and *Aeschninæ*) are to be found among submerged vegetation.

Since all of these live for a considerable length of time in the water, permanent pools and streams will

be the places to look for them. In the early spring they can be drawn ashore with a garden-rake; later in the season a water-net, one with coarse cloth to allow the water to pass freely through, must be used. In the summer-time the vegetation would interfere with the working of the rake. They will make their presence known by endeavoring to extricate themselves from the rakings. Such as are taken can be placed in a bucket of water, to be carried home in safety. A water-pail, half-full of water, with a few twigs or sticks extending well above the surface of the water, is the kind of place to keep these nymphs. The bucket should be covered with mosquito netting, to prevent the escape of any which may emerge. A good meal of mosquito larvæ (wigglers) once or twice a week will keep these nymphs thriving. The bucket should be kept outdoors, where the nymphs can get the benefit of the sunlight.

In collecting it will be well to chose only the oldest nymphs for that season's study. The older ones have longer wing-pads, which extend to about the middle of the abdomen. These will emerge during the same season.

The points for the student to observe are:

Method of feeding. For the purpose of answering this question, several can be fed in a glass vessel filled with water.

Time of day of emergence.

Actions during transformation to adult. Note especially the color of the insect just free from the nymphal case, and the characteristic colors as they appear.

These observations should be carefully written down, preceded by the field-notes. The field-notes should state the location where taken, the character of the water and vegetation, and the abundance or scarcity of the nymphs.

COMPLETE METAMORPHOSIS

SWALLOWTAIL BUTTERFLY

In the consideration of the black swallowtail butterfly, several questions have been left to be answered, and it is to be expected that other queries will arise in pursuit of answers to:

How many times does the caterpillar molt?

How many broods of butterflies come forth in your locality during the summer season?

In what positions, besides the one given, do you find the eggs?

Place one of the caterpillars upon a pane of glass on the window, and note how it endeavors to ascend the pane.

Nowhere within the realm of Natural History are biologic studies more easily conducted, or the facts acquired more remarkable or interesting, than in the study of the fascinating phases relating to life history and habits. Investigations can be most practicably conducted by establishing these caterpillars in surroundings as nearly natural as possible, where they can be frequently observed, and at times constantly watched.

Points to be observed are: temperature, moisture, proper food, and right conditions for pupation.

Care of Larvæ.— The manner of caring for the larvæ of the black swallowtail will apply to the rearing of

other caterpillars. Caterpillars should be taken with their food plant, the stem of plant placed in a bottle filled with moist sand, and this surrounded with soil in a flower-pot. In order to keep the larvæ from roving, a number of devices can be used.

Breeding-Cage.— A lamp-chimney or lantern-globe with Swiss muslin tied over the top (Fig. 188) can be placed over the food plant, or where many larvæ are being studied, a box can be well used. The soil must contain about the same degree of moisture that shaded earth will contain; it must not be soaked, but can be kept moist, in the case of the flower-pot, by keeping water in the saucer beneath the flower-pot. The earth in the screened box can be sprinkled lightly, but frequently enough to retain the right degree of moisture. Many larvæ enter the ground to pupate. Should the soil be too moist the pupa will mold and die. Should it be too dry the insect will not develop properly.

FIG. 188. A convenient breeding-cage.

A fresh supply of food should be furnished daily, and all litter removed from the breeding-cage. It will very often be found impracticable to remove a part of the old food when new food is introduced; since it is not best to disturb the caterpillar, but to wait until it has moved from the old food material to the new.

Records.— Always keep beside the breeding-cage pencil and note-paper, to make notes of every change just

at the time when the observation is taken. At no other time can it be so well or so accurately described. In fact, every observation, both in the field and laboratory, date of capture, locality, food plant, and other points suggested at the time, should be carefully set down in the pocket note-book, and this together with the breeding-cage notes placed in ink in a larger record book for permanent reference. Every study undertaken should be with a definite aim in view, and the habit should be early formed of making accurate observations. Should the note-taking and observations be dilatory, the practical and educative results will, it must be emphasized, be of little or no value.

Care of Pupæ.—When the larvæ have pupated, the breeding-cage must be removed to the cellar or to some place where the temperature is uniform and moderate. Though extreme cold may be endured, sudden changes must be guarded against.

The Adult.—When after due care and watchfulness the mature insect has come forth as the reward, it may not be a butterfly, but a moth or a skipper. Comparison with the antennæ (Figs. 167, 168, 169) will in the majority of cases enable the observer to ascertain to which class the insect in hand belongs. Is there any difference between the pupa-case of a moth and the pupa-case of a butterfly?

THE HOUSE-FLY OR BLUEBOTTLE-FLY

For the study of the life history of the fly, the bluebottle-fly lends itself readily.

Egg.—The egg of the bluebottle-fly can be procured by exposing fresh meat for several days. In winter-time, warm days should be selected for the exposure.

Larva.—When the eggs have hatched, the larvæ may be reared upon bran. Note the changes during growth. Describe the process of pupation.

The Pupa.—What is its color? Does the adult emerge through the side or the end of the pupa-case? How does the front of the head of the newly emerged fly differ from that of the same fly several hours later? How is the opening in the pupa-case made?

FIG. 189. Foot of house-fly. Greatly enlarged.

Adult.— Place fly under a glass vessel (a plain, thin water-glass will do). Rest the inverted glass upon black paper on which a few grains of granulated sugar have been placed. Note the manner in which the fly feeds upon the sugar. Place within the glass vessel substances sweet and sour, neutral and of various colors, such as different colored sugar, salt, molasses, vinegar. What substances seem to attract the fly most? What particular quality seems to form the greatest means of attraction? What senses seem to be relied upon in the discernment of these various substances?

COMPANION BOOKS.

A Manual for the Study of Insects, J. H. and A. B. Comstock. Comstock Publishing Company. Ithaca, N. Y., 1895. Price, $3.75, net; postage, 34 cents.

The Life of a Butterfly, S. H. Scudder. Henry Holt & Company. New York, 1893. Price, $1.25.

Everyday Butterflies, S. H. Scudder. Houghton, Mifflin & Company. Price, $2.

First Report of the U. S. Entomological Commission. (This

deals at length with the Rocky Mountain Locust.) U. S. Department of Agriculture, Washington, D. C.

Catalogue of the Odonata (Dragon-flies) of the vicinity of Philadelphia, with an introduction to the study of this group of insects, P. P. Calvert. Transactions Amer. Ent. Society, Philadelphia. Price, $1.

The Natural History of Aquatic Insects, L. C. Mial. Macmillan & Co. London and New York, 1895. Price, $1.75.

On the Origin and Metamorphosis of Insects, J. Lubbock. Nature Series. Macmillan & Company. New York and London, 1895.

The Butterfly Book, W. J. Holland. Doubleday & McClure. New York, 1899. Price, $3.

Moths and Butterflies, Mary C. Dickinson. Ginn & Co. Boston.

Nature Study and Life, C. F. Hodges. Ginn & Co. Boston. Price, $1.75.

CHAPTER IV

THE HABITS OF ANTS

Ants can be readily studied in artificial homes. For this reason much will be expected from the investigations of the student. The accompanying sketch shows a board with a trench, a moat, chiseled out around

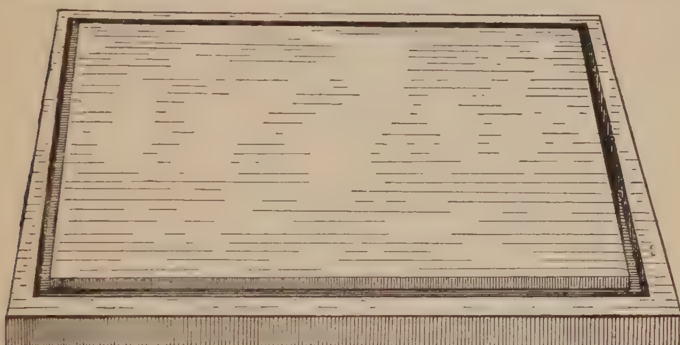


Fig. 190. Board plan for an artificial ant-nest.

the outer half. This moat is one-half inch wide and one-half inch deep; it should be well painted, to prevent the escape of any water; then fill with water to keep the ants within bounds. A strip of wood should be nailed across each of the grain ends, to prevent the board from warping. Place in the center of this board a pane of glass; surround the same with narrow strips of wood about an inch thick; place on this glass several small narrow strips about the thickness of the ant's body; these strips are to support another pane of glass equal in size with the first. Sprinkle a layer of sand

on the under glass, about the thickness of the thin strips of wood; then break a corner off the upper glass and place it on the top of the layer of sand and strips.

Now you are ready for the ants. The object, you see, is to have a place where the ants cannot get away, and yet where they can have some freedom and a home which will be open for your inspection. That they may live in the dark when not under observation, it will be necessary for you to cover this glass house with a board. The board can be lifted from time to time and the workings inside observed. You will readily see, also, that it will be necessary to have the right amount of earth or sand, else, if there is too much, the workings and tunnelings will be beneath the surface.

Ants are not hard to find under surface rocks, logs, and in old stumps. In quest of these, a garden trowel and covered tin bucket are the only things necessary. In collecting ants to establish in homes there is one form necessary — that is the queen ant, easily recognized by her large size. When she is found it is a small matter to collect a number of workers, their eggs, larvæ and pupæ. Place earth, rubbish and all, in your bucket, cover them and bring them to the artificial nest; pour the whole mass on the upper pane of glass, remove the surface rubbish by degrees, and soon the ants will begin to work their way between the panes of glass through the broken corner which you have left as an opening for them.

Colonies inhabiting hollow branches of sumac or elder are easily transferred. On one occasion a baking-powder can containing a hollow sumac knot, the home of a full colony of ants, was brought to the laboratory.

It was late in the evening, so that no attempt was made to transfer the ants at that time. During the night the little workers had discovered a hole in the side of the can, previously stopped with a toothpick; this they chewed away. When found in the morning they had taken themselves, their queen, their pupæ, eggs and larvæ, and were comfortably established in a piece of glass tubing which chanced to be near by. Here, under cover of a pasteboard box, these ants were an interesting source of study and experimentation for the students until the summer vacation, six weeks later. They were country ants, and had to learn to like city ways. For instance, at first they ran around over granulated sugar, paying no attention to it; but later, fed readily upon it. The experiments conducted with these ants you can likewise carry on.

Ascertain what foods they will eat.

Remove several from the nest, and return them the next day.

Place near the entrance to the nest a few ants of the same species but from another nest, and note the result.

Study the action of the ants in their artificial nest, the character of the tunnelings they build, how they treat the young, the larvæ, the pupæ, and the queen.

Secure a copy of "Ants, Bees, and Wasps," by Sir John Lubbock, the reading of which will suggest many valuable experiments upon the actions and instincts of this very colony of ants which you have established.

CHAPTER V

FORM AND FUNCTION

WHEN the study of Physiology is under way, comparative anatomy lends interest and adds value to the instruction. The material may be procured easily, and the few facilities required for bringing the subject-matter intelligently before the class favor an anatomical study of the skeleton or external anatomy of the grasshopper. The skeleton of the grasshopper,[1] the history of which we have already studied, will be the subject considered.

A word in beginning concerning skeletons. As every student of physiology is taught, skeletons are of two kinds: endo-skeletons, or skeletons within the body and surrounded by muscles; exo-skeletons, or those without the body, having all muscles on the interior. The skeletal structure of man comes under the first class; the rigid outer structure of insects under the second class. Every one who has studied human physiology remembers among the first topics to be found in the text is "Uses of the Skeleton," and in answer to the question, "What are the uses of the skeleton?" if he were permitted to use another's language instead of his own he would say, "To give form to the body, to protect the delicate organs, to furnish attachments for the muscles, to serve as levers for locomotion." And when an

[1] *Melanoplus differentialis.*

apt student takes up the study of the skeleton of the grasshopper he will readily see that its skeleton serves identically the same purpose as the human skeleton. The integral parts of the human skeleton we call bones; the separate portions of the insect skeleton we term sclerites. That constituent which gives bones their firmness we commonly speak of as lime; that which lends rigor to the sclerite is called *chitine.*

An examination of the body-wall of an insect shows it to be composed of a number of distinct pieces or sclerites. The lines separating these pieces are known as sutures. Sutures here, just as in the anatomy of the human skeleton, are not freely movable joints. That term is reserved for those articulations which are freely movable; for example, joints of the locust's leg.

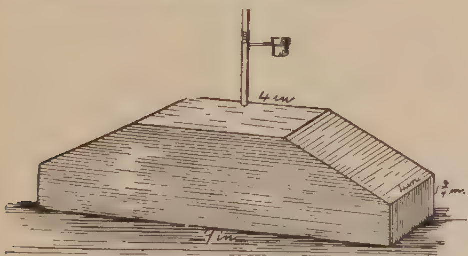


FIG. 191. Plan for simple microscope stand.

Aids in the Laboratory.— In addition to the appliances, net and lens, already mentioned, the following simply constructed materials will be of assistance:

It will at times be found advantageous to have the specimens stationary, in order that the parts being studied can be manipulated under the lens. For this purpose, Figure 191 shows a simple dissecting microscope stand, made from a 4 x 4-inch pine block nine inches

long, with two corners beveled in accordance with dimensions marked in the figure. On the side, at the middle of the four-inch table, a metal post about one-fourth inch in diameter is set in the block, and extends four inches above the table. Around this post one end of a wire sufficiently heavy to hold the weight of the lens is wrapped three or four times; the other end is made into a loop, to hold the lens. The coil on the post will slide up and down, enabling the operator to focus the lens. In some cases a small square of glass fastened on the dissecting-table will be found helpful. This enables the needles to cut more accurately. When the specimen is to be held in a stationary position, fasten to the table a slice from a large cork, or a small slip of soft wood, then pin to this the insect in the position desired.

Dissecting-needles can be made by driving the head of a sewing-needle into a wooden penholder or stick of similar size. Two of these needles will be required.

Two grades of pencil will be required, a soft pencil and a hard pencil.

The main qualification in a note-book is the paper. This should be white, of good weight, unruled, and well finished. These note-books can be made. The paper of the desired quality, high-grade flat cap of proper weight, for example, can be purchased and cut into pages about $8\frac{1}{2}$ by $6\frac{1}{2}$ inches. These can be kept in an old book cover, or heavy cardboard cover. When a drawing has been satisfactorily finished on a sheet, the sheet, accompanied by its notes, can be laid aside in serial order. It will be found advisable to make each drawing large and distinct. It is advisable to place only one drawing upon a page. Should more than one drawing appear

upon the same page, the possibility for confused impressions arises.

Preparation of Specimen. — The most humane and at the same time the most convenient way to prepare the live specimens for anatomical study is to place them for from one-half to three-quarters of an hour in a cyanide bottle. Any wide-mouthed bottle will do. Cut a piece of cyanide of potassium,[1] the size of a walnut, into small pieces, place in the bottle and cover with plaster of

FIG. 192. Cyanide bottle.

paris, add enough water to moisten the plaster of paris, allow to stand uncovered until dry; then put a circular piece of blotting-paper which will cover this plaster formation in the bottom of the bottle. This paper will keep the insect dry, and when the blotter becomes very moist it should be replaced by another. A roll of blotting-paper is frequently placed around the inside of

[1] Cyanide of potassium is a deadly poison. Great care should be exercised while handling it, to avoid inhaling the fumes or bringing the substance in contact with the mouth.

the bottle, to aid further in taking up the moisture which collects therein.

Terms Used in Defining Position and Direction.—With a specimen of the yellow grasshopper in hand it will be evident to the observer that the terms "up" and "down," "before" and "behind," and kindred terms denoting direction, are frequently indefinite in describing the location of the parts of an insect. Should these terms be applied to an insect, the body being so small and its position so easily changed, it is evident that some confusion and frequent ambiguity would be likely to attend.

In locating and describing parts, not only in the study of insect life but also in other branches of Zoölogy, a series of terms adapted to the requirements have come into use. These the student will do well to understand fully in application and significance.

The *cephalic* direction is headward. This does not necessarily refer to the head, but refers to anything extending in the direction of the head; for instance, in Figure 202 the front margin of the wing will be spoken of as the cephalic margin of the wing. The adverb denoting direction headward is *cephalad;* that is, one can say the front wing is cephalad of the hind wing.

The direction opposite from *cephalic* is the *caudal* direction, or tailward, and is used in just the same way as the term cephalic direction. The adverb from this is *caudad.*

Lateral directions refer to points on the right or left side of the body. *Laterad* is the adverbial expression used.

The *ventral* direction, or downward, refers to what

might be spoken of as the under side of the insect,—that part of the body which lies nearest the ground. The adverb is *ventrad*, and is used as in the preceding.

The other direction would necessarily have reference to the back of the insect, and *dorsal* direction is the term used here, and *dorsad* is the adverb.

Now, in order that you may understand the application of these terms, refer to Figure 202, and notice that the two wings extend laterad from the body, and that the antenna is cephalad of the base of the wing, and likewise that the wing is caudad from the antenna. The utility and application of these terms will be more readily understood with the specimen in hand and the anatomical study in progress.

EXTERNAL DIVISIONS OF THE BODY.

An examination of the whole body will readily show three divisions: the head, the thorax, and the abdomen.

The Head, apparently one piece, contains the mouth, eyes, and the long thread-like appendages known as the antennæ.

The Thorax is in the central part of the body, furnishing attachment for the wings and legs.

The Abdomen is a slender portion extending caudad from the thorax.

THE HEAD.

Fixed Parts of the Head.

Compound Eyes.—(Fig. 193, *B*) Prominently situated upon the lateral portions of the dorsal half of the head are the two prominent compound eyes. The hand-lens will reveal the honeycomb or network structure upon the surface of these eyes. If a compound microscope is at

hand, cut off one of the eyes, wash well in water, and place the head covering under the microscope, using a low-power lens. Note the hexagonal divisions of the eye. Each of these divisions constitutes the cornea for a simple eye. There being many of these in each of the eyes as seen externally, it is eminently proper to call them compound eyes. Each of the simple eyes of which they are composed is termed ocellus (plural, ocelli).

FIG. 193. Front view of head with clypeus and labrum removed to show mandibles in position. *a*, antenna; *b*, ocelli; *B*, compound eye; *C*, mandible; *d*, maxilla; *e*, maxillary palpus; *f*, labium; *g*, labial palpus. Enlarged about five times.

Simple Eyes.—Between the compound eyes in the front part of the face are located three bright, shining spots. One can be found immediately in front of the upper half of each compound eye, and one between the antennal sockets. These are the simple eyes. (Fig. 193, *b*, *b*, *b*.)

Epicranium.— The epicranium is that part of the cranial box which surrounds and holds the compound eyes and the simple eyes, and extends down the face to a distinctly marked transverse line. The epicranium is divided into three parts.

Front.— The front is that part which is on the cephalic aspect of the head.

Genæ.— The lateral portions of the epicranium are called the genæ, or cheeks.

Vertex.— That portion of the epicranium which lies on the top or dorsal aspect of the head is known as the vertex.

Clypeus.— Just below or ventrad of the front of the epicranium is the transverse suture, previously mentioned, that separates the front of the epicranium from the broad, rather short sclerite. This sclerite is the clypeus. (Fig. 194.)

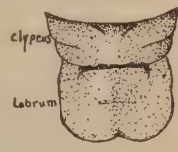


FIG. 194. Clypeus and labrum. Enlarged about five times.

Make a drawing of the cephalic aspect of the head (that part of the head which extends directly forward, and which might be commonly spoken of as the front view of the head), showing and naming all the fixed parts. In making these drawings the greatest care should be given to the accurate delineation and proper proportions of the parts, without any attempt whatever being made at shading. In the majority of cases shading will only tend to mask the details which must necessarily be brought out. The accompanying illustrations are given simply as aids, and not with the intention that any attempt whatever shall be made at their reproduction. The line-drawings will have a very different appearance from shaded illustrations, and will go much farther toward cultivating the powers of observation in the student.

Movable Parts of the Head.

Antennæ—(singular antenna) (Fig. 194, *a*).— Just between the compound eyes arise the two many-jointed antennæ. Make a drawing of these antennæ, showing the number of joints.

Mouth-parts.— Taken collectively, all the organs which aid in the mastication of food are called the mouth-parts.

Labrum.— The freely movable flap which is joined to the ventral margin of the clypeus is called the labrum, or upper lip. (Fig. 194.)

Mandibles.— By removing the labrum and clypeus the mandibles become visible. (Figs. 193, *c*, 195, *c*.) Note

FIG. 195. Front view of head, with mandibles spread out. *c*, mandible; *d*, maxilla; *e*, maxillary palpus; *f*, labium; *g*, labial palpus; *H*, hypopharynx. Enlarged about five times.

FIG. 196. Inner view of maxilla. *Lc*, lacinia; *gl*, galea; *p*, palpus; *m*, membrane. Enlarged about five times.

the direction of motion in the act of chewing. Remove one of the mandibles, and carefully draw it.

Maxillæ.—(Fig. 195, *d*.) After removing the mandibles there appears another pair of jaws, the under jaws or maxillæ. These are more complicated organs, and need to be removed with some care. If the head has not been removed from the body before this time, remove it now and pin it with the back or caudal aspect uppermost to a piece of soft wood or cork. Lift off the freely movable flap, the labium, of which we will speak later. (Fig.

197.) The labium removed, carefully pry apart the two maxillæ, endeavoring to obtain the full basal portion. With the aid of a small hand-lens, the following parts may be made out:

Lacinia.—A curved and toothed part, somewhat like the mandibles. (Fig. 169, *Lc.*)

Galea.— Lying laterad or outside of the lacinia is the spoon-shaped galea. The galea is composed of two segments. (Fig. 196, *gl.*)[1]

Palpus.—Arising from the basis of the galea is the long five-jointed palpus, or feeler. (Fig. 196, *p.*)

Make a drawing of the rear or caudal view of the maxillæ, naming all the parts.

Labium.—With the aid of a hand-lens, the labium may be analyzed into the following parts:

The two movable flaps, ligula. (Fig. 197, *L.*)

The central portion, known as the mentum. (Fig. 197, *M.*)

Arising from the basal portion of the mentum are the labial palpi. (Fig. 197, *Lp.*)

Articulating with the base of the mentum is the crescent-shaped submentum. (Fig. 197, *S.*)

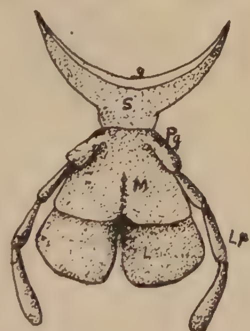


FIG. 197. Labium. *g*, gula; *S*, submentum; *M*, mentum; *Pg*, palpiger; *Lp*, labial palpus. *L*, ligula, consists of the two flaps below mentum. Enlarged seven and one-half times.

The gula and the palpiger are inconspicuous parts, which will not readily be made out without the aid of a compound lens.

[1] The basal portion of the maxilla is composed of a rectangular sclerite called the stipes, connected at the distal end with the lacinia, and at the proximal end with the small, two-jointed cardo. The larger joint of the cardo is somewhat triangular.

Make a drawing of the labium, and name the parts apparent with the lens in use.

Hypopharynx.— The hypopharynx, marked in Fig. 209 *H*, situated between the maxillæ and arising from the back wall of the mouth, may be readily made out.

Thorax.

The thorax consists of three divisions: the prothorax, bearing the front pair of legs; the mesothorax, bearing the front wings and the middle pair of legs; the metathorax, bearing the hind wings and the last pair of legs.

Prothorax.

The prothorax is made most conspicuous by the pronotum, the large sunbonnet-shaped piece covering the dorsal portion of the thorax and extending back over the mesothorax and enveloping the lateral portions of the prothorax. This pronotum is divided into four parts, beginning with the cephalic or front part. They are named (Fig. 198): *a*, præscutum; *b*, scutum; *c*, scutellum; *d*, post scutellum.

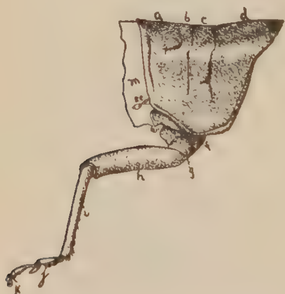


FIG. 198. Side view of prothorax with leg. *a*, præscutum; *b*, scutum; *c*, scutellum; *d*, post scutellum; *e*, episternum; *m*, membrane, connecting head with prothorax, containing the jugular sclerites; *f*, coxa of leg; *g*, trochanter; *h*, femur; *i*, tibia; *j*, tarsi; *k*, pulvillus and two claws. Enlarged three times.

Just beneath, or ventrad of the scutellum, is a small triangular piece called the episternum of the prothorax. The under and ventral portion of an insect is spoken of as the sternum; the side

or lateral portion is the pleurum; and the upper or dorsal portion is the notum.

Do the sutures dividing these sclerites extend down to the ventral margins of the pronotum? Make a drawing of the lateral view of the prothorax.

Prothoracic Leg.—For study it will be better to remove the leg from the body.

Coxa.—Note the globular joint. This is the coxa. (Fig. 198, *f*.)

Trochanter.—This second segment is a short, much smaller segment than the coxa, and more readily seen from the inner side. (Fig. 198, *g*.)

Femur.—The next segment of the leg is the femur. This is the largest and most prominent portion of the leg. (Fig. 198, *h*.)

Tibia.—Continuing outward, the next segment is the tibia, a segment more slender than the femur. How does the inner margin differ from the inner margin of the femur? (Fig. 198, *i*.)

The rest of the leg is composed of a number of freely movable segments, known collectively as the *tarsi*. In the grasshopper there are three of these movable joints, the outer or end one bearing a pair of claws and a horse-hoof-shaped pulvillus between the claws.

Make a drawing of the thoracic leg.

Mesothorax.

In order to study the mesothorax, remove the prothorax. We will study first the lateral view, then the ventral view, and lastly the dorsal view.

Episternum.—Extending from the front half of the mesothoracic coxa, dorsad to the base of the first pair of

wings, is the episternum of the mesothorax. Note that this part-way surrounds the socket of the leg, and articulates with the lateral margin of the sternum beneath. Students at this time will carefully distinguish the difference between color markings and sutures proper. (Fig. 199, *b*.)

FIG. 199. Side view of thorax. Enlarged three times.

A, Mesothorax.	B, Metathorax
a, parapteron.	*b′*, episternum.
b, episternum.	*c′*, epimeron.
c, epimeron.	*d′*, wing.
d, wing.	

Parapteron.—Just cephalad or in front of the mesothoracic wing is a very small triangular sclerite, the parapteron. This sclerite is inconspicuous, and not readily discerned.

Epimeron.— Extending from the base of the front wing to the socket of the middle leg lies the epimeron of the mesothorax. (Fig. 199, *c*.)

Make a drawing of the lateral aspect of the mesothorax.

Ventral View.—Between the mesothoracic legs, forming the ventral surface of the mesothorax, is a prominent quadrangular sclerite, nearly straight on the front margin, but on the median line of caudal margin there is a well-developed dovetailed structure, making a broad notch in this segment. (Fig. 200.)

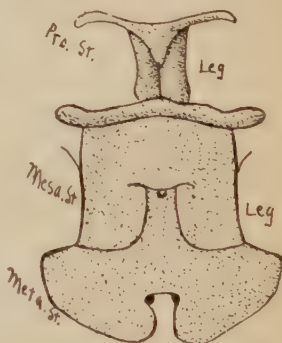


FIG. 200. Ventral view of thorax. *Pro. st.*, prosternum; *Mesa. st.*, mesosternum; *Meta. st.*, metasternum. Enlarged about three times.

Make a drawing of the ventral aspect of the mesothorax.

Dorsal View.— Lying between the mesothoracic wings is a quadrangular piece, with a raised shield-shaped center. This is the mesonotum. (Fig. 202, *C*.) Typically speaking, the notum of each division of the thorax should be composed of four sclerites, bearing the same names as those already given the pronotum. In this case we cannot locate them, since the sutures are not clearly marked. The first segment, the præscutum, is a very narrow plate, a mere line, not easily made out.

Metathorax.

Dorsal View.— The shape and divisions of the metathorax are similar to those of the mesothorax. As in the mesothorax, the sutures cannot be satisfactorily defined.

Lateral View.— The lateral aspect of the metathorax shows it to be composed of two sclerites, the episternum and the epimeron.

Episternum.— This sclerite extends from the front half of the hind coxa to the base of the hind wing. (Fig. 199, *b*.)

Epimeron.— Immediately joining the caudal margins of the episternum is the epimeron, which likewise extends from the leg socket to the base of the wing. Add a drawing of this lateral view of the metathorax to the lateral view of the mesothorax already drawn.

Ventral View.— On the ventral part of the metathorax there is but one sclerite, the metasternum.

The Metasternum.— Lying immediately caudad of the mesosternum there is a large sclerite, the central part

of which dovetails into the mesosternum. This is the metasternum. (Fig. 200.) Note that the first abdominal segment is likewise dovetailed into the posterior margin of this segment.

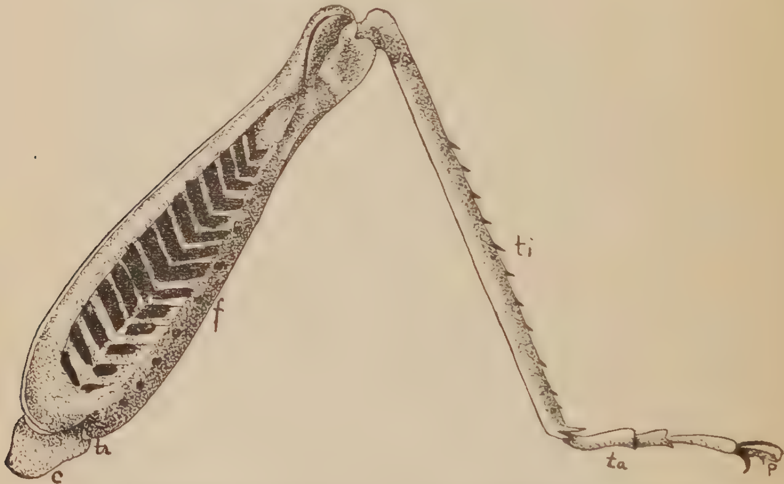
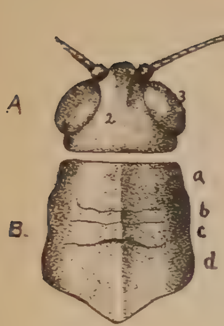


FIG. 201. Metathoracic, or jumping leg. *c*, coxa; *tr*, trochanter; *f*, femur; *ti*, tibia; *ta*, tarsi; *p*, pulvillus and two claws. Enlarged four times.

Metathoracic Leg — The metathoracic leg, though somewhat different in appearance from the prothoracic leg, already studied, is composed of a like number of parts and bearing the same relative positions and names as given in the study of the prothoracic leg. Draw the metathoracic leg, and name the parts. (Fig. 201.)

The Wings.

The two pairs of wings on each side are membranous expansions of the body-wall. They are composed of membrane strengthened by many thickened portions extending the length of the wings. These thickenings are



called veins or nerves. In the grasshopper the structure and shape of the two wings on one side differ very materially. (Fig. 202, *w w*.)

Mesothoracic Wing.—This is frequently called the tegmen. It is long and narrow, and heavier than the metathoracic wing. (Fig. 202.)

Metathoracic Wing. — The metathoracic

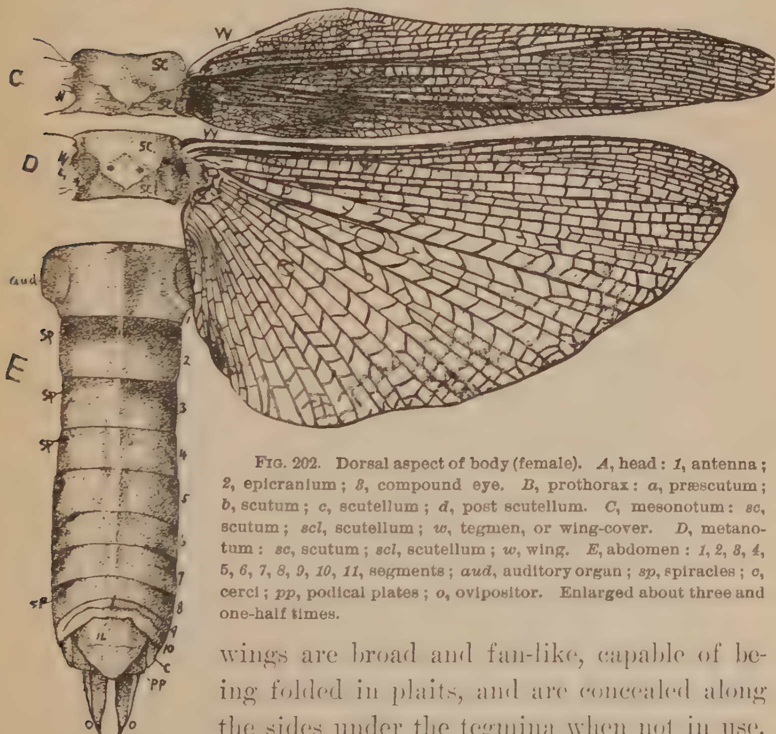


FIG. 202. Dorsal aspect of body (female). *A*, head : *1*, antenna ; *2*, epicranium ; *3*, compound eye. *B*, prothorax : *a*, præscutum ; *b*, scutum ; *c*, scutellum ; *d*, post scutellum. *C*, mesonotum : *sc*, scutum ; *scl*, scutellum ; *w*, tegmen, or wing-cover. *D*, metanotum : *sc*, scutum ; *scl*, scutellum ; *w*, wing. *E*, abdomen : *1*, *2*, *3*, *4*, *5*, *6*, *7*, *8*, *9*, *10*, *11*, segments ; *aud*, auditory organ ; *sp*, spiracles ; *c*, cerci ; *pp*, podical plates ; *o*, ovipositor. Enlarged about three and one-half times.

wings are broad and fan-like, capable of being folded in plaits, and are concealed along the sides under the tegmina when not in use. Since these are relied upon for the principal

means of flight, they are commonly called the wings. (Fig. 202.)

The Abdomen.

Among writers upon this subject there exists a difference of opinion concerning the number of segments composing the abdomen. It will be evident to the observer here, upon a careful examination, that there are eight segments on the dorsal aspect of the abdomen of the female, and nine clearly shown on the same portion of the male. As will be seen from Fig. 202, we have considered the segments caudad of segment eight in the female, and segment nine in the male, as parts of the dorsal portion, and have numbered them accordingly.

The First Segment.— The ventral portion of this segment is dovetailed into the metasternum, and by some authors has been considered a part of the metasternum. The ventral portion is widely separated from the lateral portion of the same segment, by the insertion of the hind leg.

Fig. 203. Exterior view of auditory organ. *Sp*, spiracle. Clear space is tympanum. Small dark body in center is vesicle, which is connected by vein to ganglion shown at right. Enlarged fifteen times.

The Auditory Organs. — Just dorsad of the leg in this segment is to be found on each side an oystershell-shaped opening, covered by a membrane. These are the organs of hearing, or auditory organs, and the membrane covering them is the tympanum.

Second to Eighth Segments.— The second to the eighth segments are each ring-like in form.

The connection between the ventral portion of each of these segments with the lateral portion is not a suture, but is made by a membrane. This membrane can be most readily seen in the living insect during respiration. The lateral and dorsal portions of these eight segments show no dividing suture.

Caudal Portion of Abdomen of Male.— The ninth and tenth dorsal segments are united on their lateral margins; the eleventh segment is flattened and furrowed by three deep longitudinal grooves.

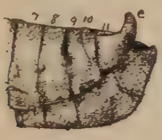


FIG. 204. Side view of male. *7*, *8*, *9*, *10*, *11*, segments; *c*, cerci. Enlarged about three times.

FIG. 205. Dorsal view of caudal appendages of male. *6*, *7*, *8*, *9*, *10*, *11*, segments; *c*, cerci. Enlarged about three times.

On each side, projecting caudad from beneath the lateral margins of the tenth tergum and curved upward, are the two appendages called the *cerci*. In this species they are slightly forked.

Immediately beneath or within these cerci can be seen two narrow plates, more readily distinguished at their caudal extremity. These are the *podical plates*.

This last of the ventral segments consists of a hood-shaped piece, rounding up over the caudal end of the body into a blunt point.

Make a drawing of the dorsal and lateral views of the abdomen of the male, naming the parts.

Caudal Portion of the Abdomen of the Female.— The eleventh segment is somewhat rounded, and is crossed by a transverse ridge.

The *Cerci* are situated similarly as in the male, and are much shorter and not forked.

The *Podical Plates* have the same position relative to the cerci as in the male, and are more prominent, curving up under the eleventh dorsal segment.

Ovipositor.— The most prominent portion of the caudal extremity of the female is the ovipositor. This consists of four horny-tipped pieces, outward curved at the extremities. For their use and the manner of using, see Figures 11, 206, and page 9.

Egg Guide.— The caudal margin of the last ventral segment extends dorsad between the two lower pieces of the ovipositor. This forms the egg guide.

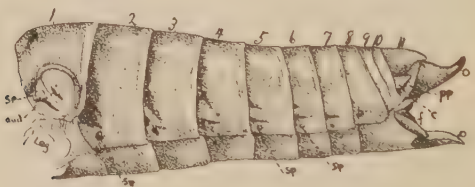


FIG. 206. Side view of abdomen (female). *1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11*, segments; *Sp*, spiracles; *aud*, auditory organ; *o*, ovipositor; *pp*, podical plates; *c*, cerci; *f*, forked organ. Enlarged about three times.

Make drawing of the lateral and dorsal views of the abdomen of the female.

Spiracles.—Just cephalad of the socket of the mesothoracic leg and a little above, is a small slit-like organ. Watch this in the living insect and you will notice two small valves or lips opening and closing.

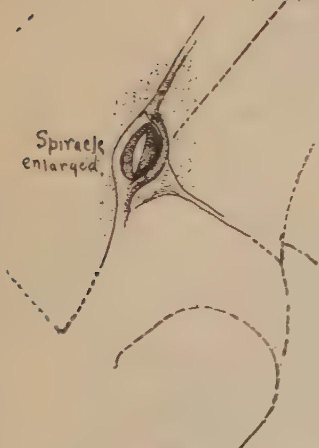


FIG. 207. Side view, showing spiracle of mesothorax with spiracle enlarged.

This is one of the openings of the respiratory system. It is called a spiracle. Examine the body of the living grasshopper and locate, if you can, other spiracles.

INTERNAL DIVISIONS OF THE BODY.

The grasshopper, agreeing with higher forms of life, has a digestive, circulatory, reproductive, respiratory, excretory and nervous system. With the facilities at hand we shall not be able to study all of these thoroughly. However, by means of the dissecting-stand, lens, and with the addition of a pair of needles, we can obtain some interesting facts.

DIGESTIVE TRACT.

Take a freshly killed specimen, clip off the wings, pin the body down by the legs to a sheet of cork or thin piece of some soft wood, and with a sharp-pointed pair

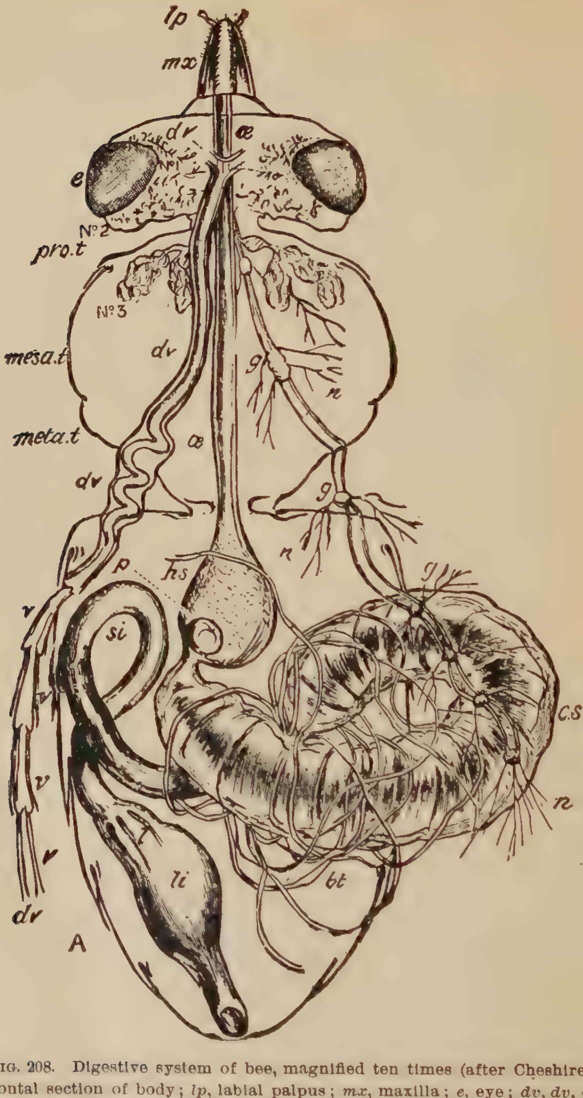


FIG. 208. Digestive system of bee, magnified ten times (after Cheshire). *A*, horizontal section of body; *lp*, labial palpus; *mx*, maxilla; *e*, eye; *dv*, *dv*, dorsal vessel; *v*, ventricles of the same; *No. 1*, *No. 2*, *No. 3*, salivary gland systems, *1*, *2*, *3*; *œ*, œsophagus; *pro. t*, prothorax; *mesa. t*, mesothorax; *meta. t*, metathorax; *g*, *g*, ganglia of chief nerve chain; *n*, nerves; *hs*, honey sac; *p*, petaloid stopper of honey sac or stomach mouth; *c. s*, chyle stomach; *bt*, biliary or malpighian vessels; *si*, small intestine; *l*, lamellæ or gland plates of colon; *li*, large intestine.

of small scissors open the specimen on the median line of the back, the full length of the body. Be careful not to cut deeper than the body-wall, lest the internal organs be disturbed; pin down the sides of the body to the cork. The specimen is now ready for study upon the dissecting-stand.

The specimen can be more readily manipulated if the block or cork of wood holding it be placed in a vessel containing just enough water to cover the specimen. The internal organs will float out and stand up more distinctly.

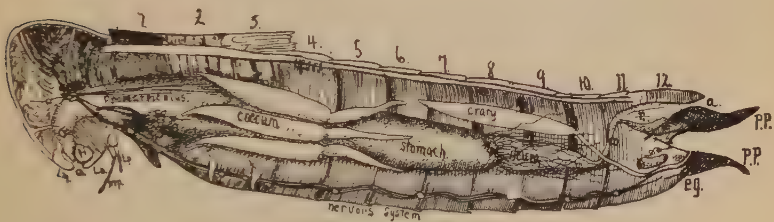


FIG. 209. Digestive, circulatory and nervous systems of female grasshopper. *1*, *2*, *3*, *4*, *5*, *6*, *7*, *8*, *9*, *10*, *11*, *12*, segments; *a–a*, digestive tract; *H*, hypopharynx; *Lb*, labium; *Lm*, labrum; *Lp*, labial palpus; *mp*, maxillary palpus; *Œ*, œsophagus; *pp*, ovipositors; *eg*, egg guide; *co*, colon; *r*, rectum. The heart is an open tube running along the back; it is so marked, but not easily shown. Enlarged three times.

The digestive system begins with the masticatory organs of the mouth, previously shown. (Figs. 193, 195.) The food is here masticated and mingled with the saliva secreted by glands lying under the esophagus. From the esophagus it passes into the crop, where it is retained until mixed with the saliva. The food then enters the gizzard-like proventriculus; the inner walls of this are lined with chitinized processes, which, by a series of contractions, grind up the food

and pass it into the stomach proper. Lying alongside this stomach, and connected with it, can be seen on each side three long tubes. These are glands (pouches or ceca), and secrete a fluid which enters the stomach. It passes forward into the crop, and acts upon the food there also. From the proximity to the stomach, these pouches are frequently called gastric ceca. Plateau and other writers equally authentic, claim that the digestive properties of the fluid secreted in them agree with the pancreatic juice of vertebrates.

The food, after leaving the stomach, passes into the intestines, the upper part of which is called the ileum, the middle part the colon, the terminal part the rectum. At the forward end of the ileum can be seen a large number of tubes (malpighian tubes) running backward. These are believed to perform the functions similar to that performed by the kidneys in the higher animals. While the food is in the stomach, and as it passes through the ileum and the colon, the nutritive portions oozing through the walls of this digestive tube enter the circulation. The waste material is carried off through the rectum.

Make a drawing of the dorsal view of the alimentary canal, and name the parts.

Nervous System.

Cut the caudal extremity of the alimentary canal; pin this far enough to the side to allow free view of the whole tract immediately beneath. Here can be seen the nervous system. It consists of a series of ganglia, or masses of nervous matter, situated under the digestive canal. These ganglia are arranged along the body just next to the digestive tract. They are placed

together, in pairs, three pairs in the thorax and five pairs in the abdomen. They are joined to each other and to the ones of the corresponding side by a cord of nerve tissue known as a commissure. This forms a double chain from the back part of the body up to the head, where a nerve band is formed around the esophagus: on the top of the esophagus are to be found the two largest ganglia in the body of the insect. From these ganglia, nerves proceed to various parts of the head. From these there go out branches of nerves to the eyes, to the antennæ, to the maxillæ and mandibles, and to other parts of the face.

Make a drawing showing the nervous system and the position of the ganglia with reference to their respective segments on the body.

FIG. 210. Respiratory system. *Sp*, spiracles, showing tracheæ permeating all parts of the body; *S*, air-sacs, which aid flight. Enlarged three times.

RESPIRATORY SYSTEM.

This insect, instead of having one portion of the body set apart for the purification of the blood, similar to animals possessing lungs, may be said to have lungs all over its system; that is, there are tracheæ branched and branched until they cover every part of the system

and extend to every organ in the system. These tracheæ do not depend upon the mouth for their supply of air, but are connected with the body-wall direct, the outer portion of this connection being known as spiracles. (Figs. 206, 210.) These spiracles have valves and openings which close and open at intervals, allowing free interchange of air. The tracheæ which run from these spiracles are membranous tubes, which do not collapse, because they are kept open by continuous rings of cartilage, similar, though on a smaller scale, to the cartilage in the windpipe of those animals possessing lungs. This distribution of air within the body tends to make the insect lighter and more capable of flight. In addition to these tracheæ, however, there are organs especially made to assist in buoying the insect when on the wing. These are commonly known as air-sacs, and connect with the spiracles as shown in the figure. (Fig. 210.)

In a live insect, notice under the lens the action of the spiracle situated just in front and dorsad of the base of the mesothoracic leg. If the student will for a time watch this spiracle it will be seen to have two lips, and that these open and close in unison with the expansion and contraction of the body-wall. This movement of the body is more manifest in the abdomen. Figure 207 shows this spiracle much enlarged.

Take out one or two of the largest tracheæ found, and study their structure by tearing them apart on the dissecting-table under the lens. When the tracheæ are pulled apart with the needles, do they sometimes appear still to be connected by a thread which ravels

off from each fragment like thread from a spool? This thread is the coiled structure which prevents the tracheæ at all times from collapsing.

Return to your outline-drawings of the external anatomy, and locate the mesothoracic abdominal spiracle.

Circulatory System.

In this locust there are no arteries and no veins. The circulatory system, so far as organs are concerned, is comprised of what we are wont to call the heart. This organ is a tube extending from about the tenth segment of the abdomen up into the head. This tube has valves along its sides which admit of entrance of blood, and do not allow that which has entered to escape until it passes out of the main opening at the end of this organ in the head.

The blood of insects differs from that of some other animals, in having no red corpuscles. It is a thin fluid, and is a mixture of blood and chyle, usually colorless, but sometimes yellowish or reddish. It is carried forward by this tube or heart to the front end, and then flows back, nourishing the organs as it passes, and likewise coming in contact with tracheæ, which are everywhere present in the body. When in contact with these tracheæ, action similar to that in the human lung takes place. It will be seen that the chief function of this heart is to conduct forward the newly made blood and unused blood from the back end of the body, pour it out at the front end of the body, and allow it to flow back like a river in its course. The action of the heart can be seen with the naked eye, or still better, through the hand-lens, in some cater-

pillars with light color and delicate skin, when they are held between the observer and the sun.

Reproductive System.

Should a female be examined a few days previous to the time of oviposition, the ovary will be found much distended and containing about one hundred eggs. These eggs are carried out through the egg-duct and

Fig. 211. Reproductive system of female grasshopper. Large egg-sac lying above stomach; oviduct leading out above egg-guide (the external opening of oviduct is above point where duct is cut by this sectional figure); *r*, rectum; *a–a*, digestive tract. Enlarged three times.

placed in position in the ground in the manner previously shown. If eggs are present in the specimen now studied, make a drawing of the lateral view of the whole ovary and of one of the eggs.

THE BEETLE.

That some conception may be obtained of the differences and resemblances existing between the relative parts in different insects, the anatomy of the rummaging ground-beetle[1] is outlined.

This is not an uncommon insect, and can be found in the woods around decaying logs, or under rocks. It

[1] *Calosoma scrutator.* Any of the larger beetles belonging to the Carabidæ, the ground-beetle family, will do.

is about an inch long and a half-inch broad. The legs, top of head, and prothorax are purple, the wing-covers dark green with wine-red borders.

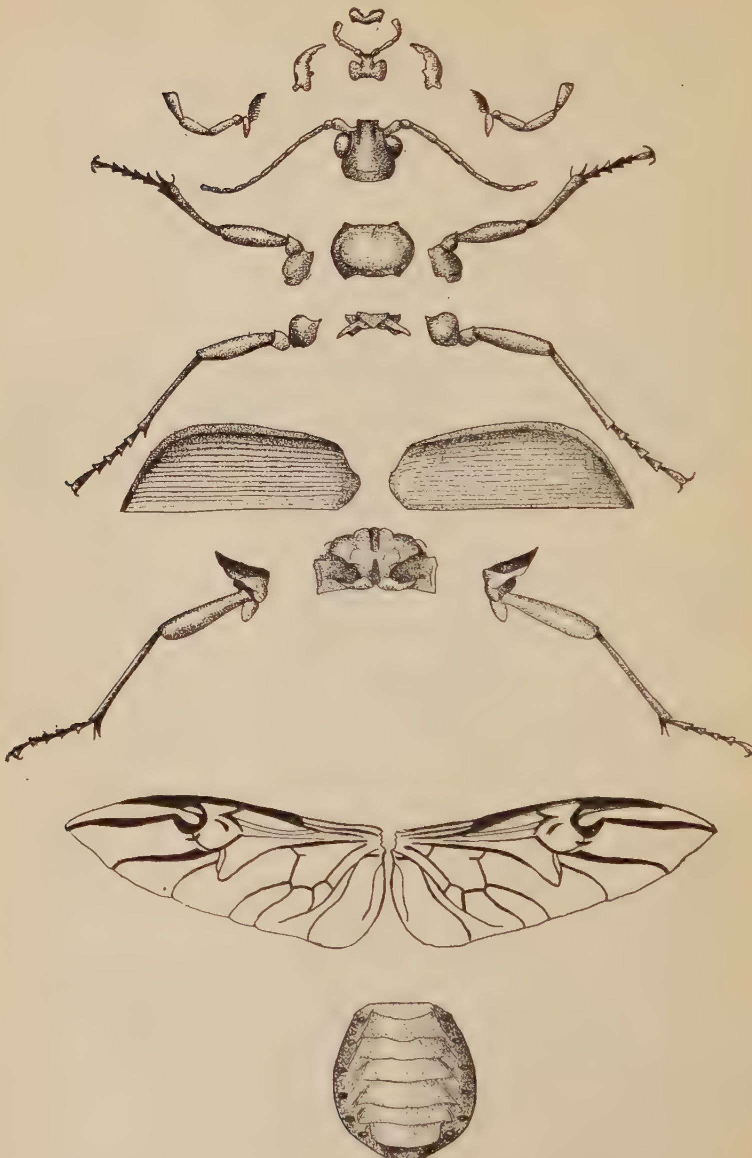
The beetle, after being treated with cyanide, as in the case of the grasshopper, should be boiled in water

FIG. 212. Rummaging ground-beetle (*Calosoma scrutator*). Enlarged.

until the parts separate easily. The different parts can be readily separated under the lens upon the dissecting-stand.

Upon a piece of white cardboard, eight by fourteen inches, fasten neatly, with a good quality of glue, the several parts in order, following the method shown in Figure 213.

Name the movable parts of the head.



Name the divisions of the body.

Name the appendages of the body.

Name the segments of the legs on one side of the body.

It will be found more convenient to number the divisions and segments, then write the numbers and corresponding names in a column on the right-hand side of the card-mount.

Boil another specimen of the same beetle; separate the parts. With a specimen of the yellow grasshopper in hand and the drawings previously made thereon, make careful observations on the comparative size, shape and relative positions of the following parts of the two insects, and place them in writing:

The head.
The prothorax.
The mesothorax.
The metathorax.
The abdomen.
The mandibles.
The maxillæ.
The eyes.
The prothoracic leg.
The mesothoracic leg.
The metathoracic leg.
The wing-covers (elytra).
The wings proper.

MOUTH-PARTS OF THE CICADA.

Since the mouth-parts of all insects are of two types, mandibulate and haustellate, it is proper that the student should be familiar with the structure of each. The mouth-parts of the grasshopper and the beetle are

examples of the mandibulate type. The mouth-parts of the cicada, sometimes called harvest-fly or locust, illustrate the structure of the haustellate mouth. Specimens just from the cyanide bottle or preserving-fluid can be studied without further preparation. Dried specimens will require boiling in water until soft and pliable. Remove the head with the beak from the body of the specimen; examine the beak before dissecting.

The primitive or earlier insects had biting mouth-parts; the haustellate or sucking mouth is a later development. This mouth structure is therefore a specialized form. That is, it has been peculiarly developed for a certain purpose, from, we are led to believe, the primitive mandibulate mouth. So, in discussing these sucking mouth-parts, it is the endeavor to trace each back to its primitive organ. The terms used, then, in naming the organs of the sucking mouth, are as far as possible the same as those used in naming the parts of the biting mouth. These terms, such as mandible and maxilla, are not used to name the parts of the sucking mouth to signify that they are used for chewing. The parts are so designated because it is generally believed that the parts so named were once a true mandible or a true maxilla. But certain conditions arose which made it necessary for these insects to secure their nourishment from the juices under the bark of trees, instead of chewing the foliage. These biting mouth-parts gradually developed by long use into tube-like structures adapted to the required work.

The names given these are given, therefore, because it is generally believed that the sucking mouth-parts, so named, represent the present development or condition

of the corresponding part, the one bearing the same name in the biting mouth. That is, we say the parts are homologous.

What are the conditions which might arise to cause this peculiar and interesting development? Let us suppose that leaf- and vegetable-feeding insects became so numerous as to devour or greatly reduce the whole food supply. Is it not evident that many insects would perish? But, if some of these insects find it possible to secure nourishment from beneath the bark of trees and dense outer covering of plants, the leaves of which have already been eaten, will they not have a better chance to exist than those whose dependence is wholly upon the foliage? Insects which have learned to extract the juices, finding this an easy and uncontested way of obtaining sustenance, continue to seek nourishment in such places. Succeeding generations having used the mouth constantly in this way, this mouth has developed and adapted itself to the work in hand, until at present there exists a well-established mechanism for the imbibing of fluids.

Fig. 214. Head of cicada, showing mouth-parts. Tip of mandible and maxilla enlarged, at the left.

With these points clearly in mind, take up the study of the cicada. Pin the head on a piece of cork, with the front of the head upward. With the dissecting-needle carefully draw out the mouth-parts contained in the long tube, the three-jointed labium. Trace these needle-like parts as near to the head as possible. How many of these needle-like parts are there? (See Fig. 214.) Each of these needles passes within the head. The larger ones are the mandibles, the smaller ones are the maxillæ. If a compound microscope is at hand, make an examination of the tips of a mandible and of a maxilla. These mandibles and maxillæ are used, not for biting, but for boring or cutting through the outer layers of trees and plants. It is likely that they also aid in bringing the juices into the esophagus.

CHAPTER VI.

KEY TO THE ORDERS AND THE PRINCIPAL FAMILIES OF INSECTS

Definition—Hexapoda.— Insects belong to the class Insecta or Hexapoda. They are small animals with bodies divided into three parts,— head, thorax, and abdomen. These are placed in longitudinal succession. They breathe, take air, by means of trachea ramifying throughout the body. The main trunks of the trachea open externally at orifices (spiracles) situated at the sides of the body. As appendages they have one pair of antennæ, situated on the head, six legs attached to the thorax, the middle division of the body, four wings in some cases, in others two, always placed on the thorax. In some instances insects have no wings. The insect body is composed of a succession of transverse rings or segments, marked in some, obscure in others. It is generally conceded that the number of these rings never exceeds thirteen. This ringed or segmented condition is more marked in the earlier stages of insect life. The number of articulated legs is six. In the developing stages these may be present or absent.

ORDERS.

A.— Insects, wingless and without rudimentary wings, showing no evidence of having descended from winged ancestors. Three pairs of legs. Metamorphosis slight. *APTERA.*

AA.— Insects, winged, or having rudiments of wings, showing evidence of having descended from winged ancestors. Metamorphosis varied.

B.— Mouth-parts biting, four wings.

C.— Front wings leather-like, usually narrower than hind wings, which are delicate, and fold in repose in the manner of a fan. Metamorphosis incomplete. *ORTHOPTERA.*

CC.— Front and hind wings similar in texture, frequently with many cross-veins forming a network. Little or no fan-like action in the closing of hind wings. Metamorphosis incomplete in some forms, complete in others. *NEUROPTERA.*

CCC.—Wing-covers, *i. e.*, the upper pair, shell-like, meeting in a straight line along the back, forming cases over and concealing the delicate infolded membranous wings proper. Metamorphosis complete. *COLEOPTERA.*

CCCC.— The four wings membranous. Front wings larger than hind wings; hind wings always small, and not folding fan-like in repose. Mouth-parts mandibulate, but in many forms there is present a tubular proboscis; the mandibles being in the form of jaws and the maxillæ and labium fitted for taking liquid food. *HYMENOPTERA.*

BB.— Mouth suctorial. Four wings.

C.— Mouth perfectly suctorial.

D.— The front pair wings leather-like, with more membranous apex (Heteroptera — see page 184), or entire wing parchment-like or membranous (Homoptera — see page 185.) Metamorphosis incomplete. *HEMIPTERA.*

DD.— Four large wings covered with scales. Metamorphosis complete. *LEPIDOPTERA.*

CC.— Mouth imperfectly suctorial. Four very narrow fringed wings. Very small insects. Metamorphosis incomplete. *THYSANOPTERA.*

BBB.— Mouth suctorial, mandibulate and maxillate bristles present in some forms, and used for piercing. Two wings, the hind wings being represented by a pair of knobbed, thread-like organs. Metamorphosis complete. *DIPTERA.*

APTERA.

A.—Abdomen composed of ten segments; ventral tube wanting on its first segment. Suborder *Thysanura.* (Fish Moths.)

AA.—Abdomen composed of not more than six segments, the first being furnished with a ventral tube. Suborder *Collembola.* (Springtails.)

ORTHOPTERA.

A.—Posterior femora fitted for walking, *i. e.*, resembling those of the other legs. Organs of flight of immature forms in normal position. Insects mute.

B.—Anterior wings leathery, very short, without veins, meeting in a straight line; posterior wings when present folded to the middle of the anterior margin; tarsi three-jointed, the pulvillus wanting; cerci horny, resembling forceps. *Forficulidae.* (Earwigs.)

BB.—Anterior wings parchment-like, thickly veined; posterior wings folded to the base, (except certain *Phasmidae*, which are wingless); tarsi five-jointed; cerci soft, jointed or without joints.

C.—Body oval, depressed; head wholly or almost wholly withdrawn beneath the pronotum; pronotum shield-like, transverse; legs compressed; cerci jointed; rapid-running insects. *Blattidae.* (Cockroaches.)

CC.—Body elongated; head free; pronotum elongated; legs slender, rounded; cerci jointed or without joints; walking insects.

D.—Front legs fitted for grasping; cerci jointed. *Mantidae.* (Praying Mantis.)

DD.—Front legs simple; cerci without joints. *Phasmidae.* (Walking-Sticks.)

AA.—Posterior femora fitted for jumping, *i. e.*, very much stouter or very much longer, or both stouter and longer, than the middle femora; organs of flight of immature forms reversed; stridulating insects.

B.—Antennæ shorter than body; tarsi three-jointed; organs of hearing situated in the first abdominal segment; stridulating organs situated in hind femora and the costal area of the tegmina. *Acrididae.* (Grasshoppers.)

BB.—Antennæ longer than body, setaceous; tarsi four- or

three-jointed; organs of hearing situated in the anterior tibæ and also in the prosternum.

C.—Tarsi four-jointed; ovipositor (when exserted) forming a strongly compressed, generally sword-shaped blade. *Locustidae.* (Katydids.)

CC.—Tarsi three-jointed; ovipositor (when exserted) forming a nearly cylindrical, straight, or occasionally upcurved needle. *Gryllidae.* (Crickets.)

NEUROPTERA.

A.—With four or two wings well developed.

B.—Antennæ inconspicuous, awl-shaped, short and slender.

C.—First and second pairs of wings nearly of same length; tarsi three-jointed. *Libellulidae.* (Dragon-Flies.)

CC.—Second pair of wings either smaller or wanting; tarsi four- or five-jointed. *Ephemeridae.* (Day-Flies.)

BB.—Antennæ usually conspicuous, setiform, filiform, clavate, capitate, or pectinate.

C.—Tarsi two- or three-jointed; wings unequal.

D.—Hind wings smaller. *Psocidae.* (Book-Lice.)

DD.—Hind wings of same size, or broader than fore wings; anal area large, of simple venation, folded. *Perlidae.* (Stone-Flies.)

CC.—Tarsi four-jointed; wings unequal. *Termitidae.* (White Ants.)

CCC.—Tarsi five- (sometimes apparently but four-) jointed.

D.—Hind wings with no anal space, not folded.

E.—Mouth more or less prolonged into a beak. *Panorpidae.* (Scorpion-Flies.)

EE.—Mouth not prolonged into a beak. *Hemerobidae.* (Lacewing-Flies.)

DD.—Hind wings with a folded anal space.

E.—Wings reticulate. *Sialidae.* (Dobson-Flies.)

EE.—Transverse veins rather few. *Phryganeidae.* (Caddis-Flies.)

AA.—Wings rudimentary or wanting.

B.—Mouth prolonged into a beak. *Panorpidae.* (Certain Scorpion-Flies.)

BB.—Mouth not prolonged into a beak.

C.—Tarsi five-jointed. *Phryganeidae.* (Certain Caddis-Flies.)

CC.—Tarsi four-jointed. *Termitidae.* (Certain White Ants.)

CCC.—Tarsi two- or three-jointed.

D.—Wings absent; or two rudimentary, leathery. *Psocidae.* (Certain Book-Lice.)

DD.—Four rudimentary wings, veins visible. *Perlidae.* (Certain Stone-Flies.)

CCCC.—Tarsi one- or two-jointed. *Mallophagidae.* (Bird-Lice.)

COLEOPTERA.

A.—Head not prolonged into a narrow beak.

B.—Tarsi five-jointed.

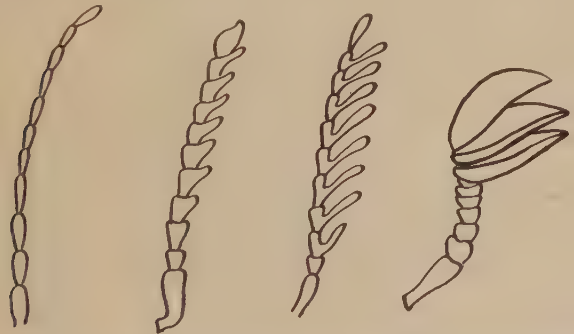


FIG 215. Various forms of antennæ of beetles. *a*, filiform, or thread-like; *b*, serrate, or saw-like; *c*, pectinate, or comb-like; *d*, lamellate, having an enlarged end, composed of plates.

C.—Antennæ with terminal joints leaf-like (lamelliform; *i. e.*, broader and flatter than basal segments.) (Lamellicornia.)

D.—The ventral surface of abdomen divided into five segments; elytra cover entire dorsal surface of abdomen;

mandibles in males large, and armed with projections or teeth. *Lucanidae.*
(Stag Beetles.)

DD.— The ventral surface of abdomen divided into six segments; elytra do not usually cover entire dorsal surface of abdomen. *Scarabaeidae.*
(Chafers; June-Bugs.)

CC.—Antennæ never lamelliform, but thread-like or nearly so. (Adephaga.)

D.— Legs fitted for running. Terrestrial insects.

E.— Clypeus extending laterally in front of base of antennæ; *i. e.*, antennæ inserted in front above base of mandibles. *Cicindelidae.*
(Tiger Beetles.)

EE.— Clypeus not extending laterally in front of base of antennæ; *i. e.*, antennæ coming from the side of the head between base of mandibles and the eyes. *Carabidae.*
(Ground Beetles.)

DD.— Legs, especially the hind legs, fitted for swimming; not capable of ordinary walking. *Dytiscidae.*
(Predaceous Diving Beetles.)

BB.— Front and middle tarsi five-jointed, hind tarsi four-jointed. (Heteromera.)

C.— Prothorax wider than head; front coxæ separated, not protruding; body and wing-covers firm. *Tenebrionidae.*
(Darkling Beetles.)

CC.— Prothorax narrower than head; front coxæ near together, protruding; body and wing-covers soft. *Meloidae.*
(Blister Beetles.)

BBB.— Tarsi four-jointed (apparently), but with a small indistinct joint between the third and fourth clearly visible segments. (Phytophaga.) (See Figure 216.)

C.— Body elongate, antennæ long, frequently as long as the body or longer; the larvæ are borers. *Cerambycidae.*
(Long-horned Beetles.)

CC.— Body short, more or less oval, antennæ short. *Chrysomelidae.*
(Leaf Beetles.)

Fig. 216. Tarsi of beetle, showing indistinct fourth segment. (After Comstock.)

BBBB.— Tarsi variable, antennæ club-shaped; *i. e.*, the distal joints enlarged; or antennal joints from third outward more or less saw-like, the saw-teeth being on the inner edge. (Polymorpha.)

C.— Tarsi five-jointed.

D.— Maxillary palpus as long or longer than the antennæ. *Hydrophilidae.* (Water Scavengers.)

DD.— Maxillary palpus plainly shorter than the antennæ.

E.—Abdomen with seven or eight visible ventral segments. Integument soft. *Lampyridae.* (Lightning-Bugs.)

EE.—Abdomen with five visible segments; integument firm.

F.—Anterior coxæ globular, and projecting but little from the coxal cavities.

G.— Hind angles of prothorax more or less prolonged backward. Prothorax fitting loosely to the after-body, thus admitting free nodding movements. *Elateridae.* (Click Beetles.)

GG.— Hind angles of prothorax not prolonged backward. Prothorax fitting closely to after-body, permitting no nodding motion. *Buprestidae.* (Metallic Wood-Borers.)

FF.—Anterior coxæ conical, *i. e.*, long, oblique, and projecting prominently from the coxal cavities. Small or moderate-sized beetles. *Dermestidae.* (Carpet Beetles; Buffalo Moths.)

CC.— Tarsi apparently three-jointed (the apparent third joint consisting really of two small segments). *Coccinellidae.* (Ladybirds.)

CCC.— Tarsi variable, being three-, four- or five-jointed.

D.—Abdomen flexible, with seven or eight segments visible below; elytra very short, leaving greater part of abdomen exposed. *Staphylinidae.* (Rove Beetles.)

DD.—Abdomen firm; elytra usually covering the body; (the elytra of some Silphidæ are short, exposing at most the last three dorsal segments of abdomen.)

E.—Legs fitted for swimming. *Gyrinidae.* (Lucky-Bugs; Whirligig Beetles.)

EE.— Legs fitted for walking. *Silphidae.* (Carrion Beetles.)

AA.— Head prolonged in front, forming a beak. *Rhynchophora.*

B.— Head drawn out into a proboscis. Antennæ usually elbowed, *i. e.*, basal joint longer, and when directed laterally the other joints may be directed forward. *Curculionidae.* (Curculios or Weevils.)

BB.— Head not drawn out into a proboscis; *i. e.*, the beak is very short; antennæ short with a broad club; tibia usually toothed on the outer side. *Scolytidae.* (Engravers.)

HYMENOPTERA.

A.— With abdomen broad at the base. The thorax and abdomen having a broad connection instead of being connected by a more or less thread-like joint. Extremity of female equipped with saw or boring apparatus, usually more or less concealed; vegetable feeders. (Phytophaga or Sessiliventres.)

B.— Front tibia with two apical spurs; abdomen of female equipped with a pair of saws. *Tenthredinidae.* (Saw-Flies.)

BB.— Front tibiæ with one apical spur; abdomen of female furnished with a borer. *Siricidae.* (Horn-Flies.)

AA.— The abdomen connected with what appears to be the thorax by a slender joint or petiole; in some long and thread-like, in others short. (Petioliventres.)

B.— Trochanters of two pieces, female with ovipositor. (Parasitica.) (Parasitic Insects.)

C.— Wings without a system of cross-veins forming inclosed cells; the main direction of the veins being lengthwise of the wing. *Chalcididae.* (Chalcis-Flies.)

CC.— Wings with well-developed series of veins and cross-veins. *Ichneumonidae.* (Ichneumon-Flies.)

BB.— Trochanters undivided, abdomen consisting of three, four or five visible segments. Insects of bright metallic colors; abdomen convex above, flat or concave below. (Tubulifera.) *Chrysididae.* (Cuckoo-Flies.

BBB.—Trochanters undivided; abdomen composed of six or seven visible segments; female with retractile sting. (Aculeata.)

C.—Body with hairs on it more or less plumose. *Apidae.* (Bees.)

CC.—Hairs of body not plumose.

D.—First abdominal segment (and sometimes second also) forming a knot or node on upper side. *Formicidae.* (Ants.)

DD.—First and second abdominal segments without knot or node.

E.—Wings folded in plaits when at rest.

F.—Tibiæ of the middle legs with a single terminal spur, tarsal claws bearing a tooth. *Eumenidae.* (Solitary Wasps.)

FF.—Tibiæ of the middle legs with two terminal spurs; tarsal claws not toothed. *Vespidae.* (Social Wasps; Hornets.)

EE.—Wings not folded in plaits when at rest.

F.—Pronotum extending back on sides to the tegulæ. (See Fig. 217.)

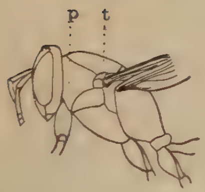


FIG. 217. Drawn from specimen, by Miss M. E. Wise.

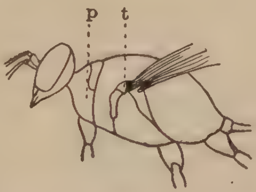


FIG. 218. Drawn from specimen, by Miss M. E. Wise.

G.—Legs of normal length; many wingless forms. *Scoliidae.* (Underground Stingers.)

GG.—Legs very long; no wingless forms. *Pompilidae.* (Runners.)

FF.—Pronotum not extending back to the tegulæ. No wingless forms. (Fig. 218.) *Sphegidae.* (Thread-waisted Wasps; Mud-daubers.)

HEMIPTERA.

A.— Front of head not touching the coxæ; distal portion of wing generally thinner than basal part. *(Heteroptera.)*

B.—Antennæ as long as the head at least. Terrestrial Heteroptera excepting one family, Hydrobatidæ.

C.— Last segment of tarsi more or less split; claws arising from side of tarsi.

D.— Body usually elongate; beak four-jointed; tarsi two-jointed. Second and third pair of legs unusually long. *Hydrobatidae.* (Water-Striders.)

CC.—Last segment of tarsus entire; claws arising from end of tarsi.

D.—Antennæ four-jointed.

E.—Wing-covers resembling network; tarsi two-jointed. *Tingitidae.* (Lace-Bugs.)

EE.—Wing-covers of various forms or rudimentary, but not resembling lacework.

F.— Beak three-jointed, curved. Front femora somewhat thickened. *Reduviidae.* (Assassin-Bugs.)

FF.— Beak four-jointed.

G.— Ocelli present.

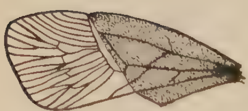


FIG. 219. Wing of Coreidæ, showing venation. (After Comstock.)

FIG. 220. Wing venation of Lygæidæ. (After Comstock.

FIG. 221. Wing venation of Capsidæ. (After Comstock.)

H.—Antennæ inserted on upper part of head; venation of wing according to figure. *Coreidae.* (Squash-Bugs.)

HH.—Antennæ inserted well down on side of head; venation of wing according to figure. *Lygaeidae.* (Chinch-Bugs.)

GG.— Ocelli wanting; venation of wing according to figure. *Capsidae.* (Leaf-Bugs.)

DD.—Antennæ five-jointed (rarely four-jointed); two ocelli, tibia bearing very short spines or none, tarsal claws with appendages. *Pentatomidae.*
(Stink-Bug Family.)

BB.—Antennæ apparently absent, but really present, situated on under side of head and closely appressed to head, sometimes placed in pocket in front of each eye. Aquatic Heteroptera.

C.—Hind tarsi without claws.

D.—Fore tarsi of usual form, with two claws; head inserted in prothorax. *Notonectidae.*
(Backswimmers.)

DD.—Fore tarsi flattened with a fringe of hairs on the edge, and without claws. Head overlapping the prothorax. *Corisidae.*
(Water-Boatmen.)

CC.—Hind tarsi with two claws.

D.—Abdomen with terminal respiratory tube composed of two grooved thread-like organs. Not retractile. Legs not flattened for swimming. *Nepidae.*
(Water Scorpions.)

DD.—Abdomen with two terminal strap-like appendages, retractile, frequently withdrawn from sight. Legs flattened for swimming. *Belostomidae.*
(Giant Water-Bugs.)

AA.—Front of head much bent inward so that it touches the coxæ. Wings of same texture throughout. Suborder Homoptera.

B.—Tarsi usually three-jointed.

C.—With three ocelli, usually large insects; males possess musical organs. *Cicadidae.*
(Cicadas.)

CC.—With two ocelli, males without musical organs.

D.—Antennæ inserted on sides of cheeks beneath the eyes. *Fulgoridae.*
(Lantern-Flies.)

DD.—Antennæ inserted in front of and between the eyes.

E.—Prothorax prolonged backward into a hood or processes of varied forms. *Membracidae.*
(Tree-Hoppers.)

EE.—Prothorax not prolonged backward.

F.—Hind tibiæ armed with many spines. *Jassidae.*
(Leaf-Hoppers.)

FF.— Hind tibiæ armed with one or two stout teeth, with short stout spines at tip. *Cercopidae.* (Spittle Insects.)

BB.— Tarsi usually two-jointed.

C.— Legs long and slender, not fitted for leaping; antennæ three- to seven-jointed. *Aphididae.* (Plant-Lice or Green-Flies.)

CC.— Hind legs fitted for leaping; antennæ nine- or ten-jointed. *Psyllidae.* (Jumping Plant-Lice.)

BBB.— Tarsi usually composed of one joint. Minute insects; males with one pair of wings, females wingless and much degraded, so that most of the external organs and appendages cannot be distinguished. *Coccidae.* (Scale Insects.)

LEPIDOPTERA.

A.—Antennæ knobbed at tip, or thickened near the tip; never feather-like or with process projecting from the sides. Hind wings without frenulum but with the humeral area of hind wing extended forward under the front wing. (Butterflies.)

B.— First pair of legs different from the other pairs; generally much smaller and not used as legs.

C.— Front pair of legs very small, claws wanting. *Nymphalidae.* (Brush-footed Butterflies.)

CC.— Front pair of legs but little reduced in size; claws present. *Lycaenidae.* (Blues and Coppers.)

BB.— First pair of legs like the other pairs.

C.— Front tibiæ without pads; claws toothed. *Pieridae.* (Cabbage Butterflies.)

CC.— Front tibiæ with a pad.

D.— Claws large and simple; *i. e.*, not toothed; antennæ generally straight at tip. *Papilionidae.* (Swallowtails.)

DD.— Claws short and thick, and toothed at the base; antennæ generally recurved at tip. *Hesperidae.* (Skippers.)

Before undertaking the systematic study of AA, the second group, or moths, an understanding of the wing structures of

these insects is necessary. If the under side of the wing be moistened with benzine or chloroform, by means of a small camel's-hair brush, it will be noticed that the membranous portion of the wing is supported by veins or nervures. The relative positions of these veins remain fairly constant in the various families, and thus these veins afford clear and ready means of comparison. For these veins, various systems of arrangement and nomenclature are extant. The one used here was proposed by Redtenbacher, and has been modified and extended by Comstock. The principal trunks of the veins bear the Roman numerals I, II, III, etc.; the branches of each of

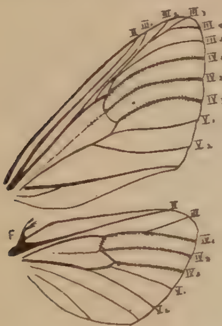


Fig. 222. Wings of a Notodontid, showing venation. *F*, frenulum. (After Comstock.)

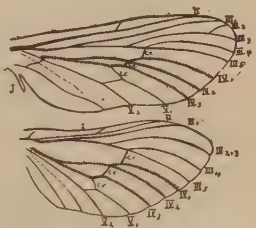


Fig. 223. Wing of a Hepialid moth, showing plan of venation. (After Comstock.)

these veins, where branches exist, are numbered III_1, III_2, III_3, etc. The system considers I (the front margin of wing) simple, II simple, III possessing five branches, IV with three branches, and V with two branches. Those main veins which come after V are called anal veins. They are generally simple. This arrangement has reference to the early or primitive plan of the wing. This condition is shown in Figure 222. This arrangement is greatly modified in some of the higher types, by the elimination of branches or even trunks and by the coalescence of veins for part or for their entire length.

AA.—Antennæ of various forms, frequently feather-like, rarely knobbed at tip, but in such cases the hind wing bears a frenulum.

B.— Hind wings with three anal veins; small moths, palpi generally well developed; when palpi are not well developed, antennæ are at least as long as the front wings. Fringe on inner angle of hind wings longer than elsewhere.

C.— The second anal vein of the hind wings forked near the base. *Tortricidae.* (Leaf-Rollers.)

CC.— The second anal vein of the hind wings not forked near the base. *Tineidae.* (Leaf-Miners and Clothes-Moths.)

BB.— Hind wings with less than three anal veins; moths of

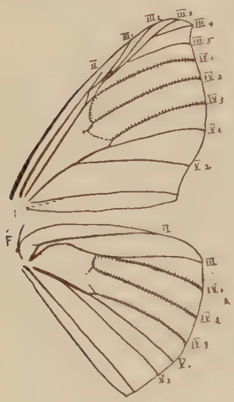


FIG. 224. Wings of a Geometrid, showing venation. *F*, frenulum. (After Comstock.)

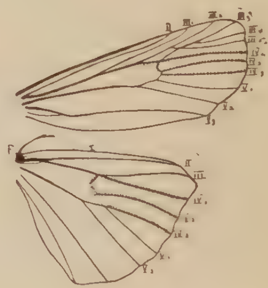


FIG. 225. Wings of a Noctuid, showing venation. (After Comstock.)

medium or large size, palpi generally small; antennæ moderate in length. Fringe on inner angle of hind wing not noticeably longer than elsewhere.

C.—Vein IV_2 of front wing standing midway between IV_1 and IV_3 or nearer IV_1 than IV_3.

D.— Frenulum present.

E.—Antennæ in length spindle-shaped; *i. e.*, thicker in the middle and tapering toward the tip and base; in breadth, *i. e.*, in cross-section, shaped like a prism. *Sphingidae.* (Hawk Moths or Humming-Bird Moths.)

EE.—Antennæ not spindle-shaped, nor prismatic.

F.—Tarsi as short as tibia, hairy; stoutly built moths. Wing venation according to figure. (Fig. 222.) *Notodontidae.*
(Prominents.)

FF.—Tarsi long and naked; slightly built moths. Wing venation according to figure 224.
Geometridae.
(Measuring-Worms.)

DD.—Frenulum absent; humeral angle of hind wing extended forward under front wing; proboscis absent, legs without spurs. *Saturniidae.*
(Cecropia Moths and others.)

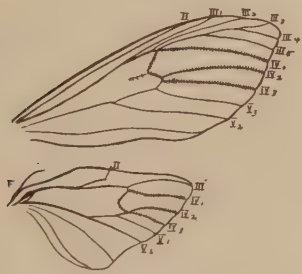


FIG. 226. Wings of an Arctiid, showing venation. (After Comstock.)

CC.—Vein IV_2 of front wing arising from IV_3 or standing nearer IV_3 than IV_1; ocelli present; antennæ bristle or thread-like; night-flying moths. (See Figure 225 for venation.)

D.—Vein II of hind wing distinct from vein III or united for but a very short distance near base of wing. (See Figure 225.) Generally dull-colored moths.
Noctuidae.
(Owlet Moths.)

DD.—Vein II of hind wing united with III for a considerable distance from base. (See Fig. 226.) In many cases these moths are conspicuously striped or spotted.
Arctiidae.
(Tiger Moths.)

DIPTERA.

A.—Antennæ with more than six segments, not ending in a style or bristle; palpi slender and flexible, four- or five-jointed. (Orthorrhapha Nemocera.)

B.— Dorsum of thorax with a distinct V-shaped suture. (See Fig. 228.) Legs unusually long. *Tipulidae.* (Crane-Flies.

FIG. 227. *a*, antenna of a Bombyliid; *b*, antenna of a Syrphid; *c*, antenna of a Muscid; *d*, antenna of a Tabanid. Drawn from specimens, by Miss M. E. Wise.

BB.— Dorsum of thorax without distinct V-shaped suture.

C.— Margins of wings and each of the wing veins fringed with flat scales. Antennæ with whorls of hair or plumes; plume generally dense in male and sparse in female. *Culicidae.* (Mosquitoes.)

CC.— Margin of wing and each of wing veins without fringe of flat scales; antennæ thick, straight, shorter than the thorax. Legs comparatively short and stout. *Bibionidae.* (March-Flies.)

FIG. 228. Thorax of crane-fly, showing V-shaped suture. (After Comstock.)

AA.— Antennæ three jointed, with distal joint marked with from five to eight rings or annuli. Bristle when present is usually at end, not on upper side of last segment. Palpi one- or two-jointed. (Orthorrhapha Brachycera.)

B.—Antennæ three-jointed, the second joint usually short. Third segment frequently annulated. (See Fig. 227, *d*.) *Tabanidae.* (Horse-Flies.)

BB.—Antennæ three-jointed, the terminal joint not distinctly

divided. Body frequently fringed with down or covered with hairs, giving a bee-like appearance. *Bombyliidae.* (Bee-Flies.)

BBB.—Antennæ three-jointed, with terminal appendage of diverse form and structure. Mouth forming a short, projecting horny beak; strong feet. Predaceous flies. *Asilidae.* (Robber-Flies.)

AAA.—Antennæ composed of not more than three joints and an arista;[1] arista not arising from end of last segment; no arched frontal suture over the antennæ. (See Fig. 227, *b*.) (Cyclorrhapha Aschiza.)

B.—Vein-like thickening between veins III and V. (See Fig. 226.) *Syrphidae.* (Hover-Flies.)

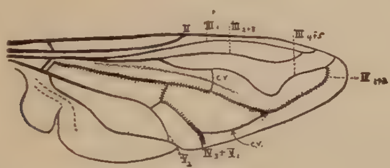


FIG. 229. Wing venation of a Syrphid. (After Comstock.)

AAAA.—Antennæ consisting of three joints and an arista; frontal suture over antennæ well marked, extending downward along each side of face. (Cyclorrhapha Schizophora.)

B.—Arista on upper side of antennæ. For wing venation see Figure 230. *Muscidae.* (House-Fly Family.)

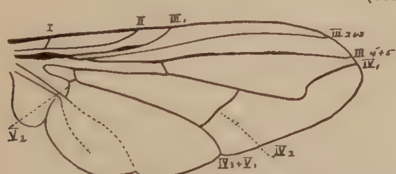


FIG. 230. Wing of a Muscid. (After Comstock.)

The suborders Orthorrhapha and Cyclorrhapha, the main subdivisions, chiefly based upon pupal characters, are omitted in this scheme. Instead of a dichotomous arrangement, the principal families of the order are placed under the four divisions of Brauer.

[1]A bristle-like appendage.

NOTE.

After the completed manuscript was in our hands, we asked the author to prepare this appendix. It is not a part of the general plan of the book, but is placed here, at our request, as a brief treatise for reference only.

THE PUBLISHERS.

APPENDIX

INJURIOUS INSECTS, AND MODES OF DEALING WITH THEM

(For reference.)

FARM PRACTICES.—CULTURE

Whenever an insect appears in injurious numbers it becomes highly essential that a knowledge of its life history should be acquired. In the life of many insects there is a stage where methods of culture or farm practices will destroy the insects and prevent the possibility of damage from them or from their direct offspring. As illustrations, in alfalfa-growing regions, native grasshoppers lay their eggs in the alfalfa-field late in the fall of the year. These eggs hatch in the early spring and the young defoliate the alfalfa. They mature during the summer and lay eggs on the same ground. These will destroy the next year's alfalfa yield. If the alfalfa lands are thoroughly harrowed in the early spring with a disk harrow, the egg-pods are turned out of the ground and become a prey to birds and other insects. The exposure to sun and rain and the sudden changes in temperature destroy any which escape the birds and insects. The disking, likewise, materially increases the alfalfa yield.

The Hessian fly seems to have but one vulnerable point in its life; that is the time from wheat harvest until wheat sowing. The females of the early fall brood seem to be so timed that they lay all their eggs

before the last of September. Now, if the summer volunteer wheat is kept under, and wheat, rye and barley sowing is postponed until after the middle of September, it is evident that, since the Hessian fly can live only on these cereals, the young of the fall brood will not find proper nourishment.

Clean culture is everywhere and at all times to be commended, since rubbish of any kind and all kinds offers a refuge for the hibernation of insects, and weeds furnish nourishment for the growing insects. The following illustrates the point: crab-grass had been allowed to grow undisturbed through the summer in a young pear orchard. The crab-grass was plowed under in October. The leaf-eating insects, driven from the crab-grass, defoliated the young pear trees. These began to bud again, when a heavy frost occurred, biting the tender buds and killing many of the trees.

Preventives.— Clean, thorough culture. Bands of cotton are placed around the bases of trees, then covered with tar or similar harmless adhesive substances. This is done to prevent the ascent of climbing cut-worms, canker-worms, or the wingless female parent of the canker-worm. Ditching, with occasional post-holes in the ditch, for army-worms and chinch-bugs. (See page 136.)

Rotation of Crops.— Crop rotation is very effective. The corn-root worm rarely effects serious damage until land has been planted in corn at least three years successively. As before stated, the best means of prevention is thorough and clean culture. When insects become destructive they should be reckoned as a factor in deciding proper modes of cultivation.

Insecticides.— In dealing with insects directly, we have three classes to combat:

1. Those with biting mouth-parts, having jaws, and masticating their food.

2. Those with sucking mouth-parts, having a beak, through which fluid nourishment is taken.

3. Insects of either of the above classes, but inaccessible, such as insects on roots of trees or in bins of grain.

For Insects that Chew their Food.—

ARSENITES.— Since the first class bite off portions of their food, it is evident that poisonous substances placed thereon will be taken into the digestive system with the food.

SPRAYS.— Paris green, an aceto-arsenite of copper, contains, when pure, about 58% of arsenic. The amount of arsenic contained is variable. An average analysis is: arsenic, 47.68%; copper oxide, 27.47%; sulphuric acid, 7.16%; moisture, 1.35%; insoluble material, 2.32%. In water, Paris green is practically insoluble. The spray formula generally used is Paris green one pound, freshly slaked lime two pounds, and 150 gallons of water. The addition of the lime is to prevent any caustic injury to the foliage. This formula varies somewhat with the plants sprayed. It can be used upon potatoes, apple trees, and most species of shade trees. For stone fruits the amount of water should be doubled, since leaves such as peach leaves are easily injured by arsenites. This spray when being used must be kept in a constant state of agitation, or the poison will settle. The liquid at the bottom of the

tank will be so strong as to injure the foliage, while that at the top will be useless. (See requisites for a spraying-pump.)

FIG. 231. The "Pomona" spray-pump, mounted on end of barrel. Used to spray with arsenical mixtures.

LONDON PURPLE.— This is a by-product in the manufacture of aniline dyes. It is an arsenite of lime, and contains a variable amount of arsenic. The average may be considered from 30% to 50% arsenic. It is a finer powder than Paris green, likely to remain longer

in suspension. It sometimes contains much soluble arsenic, however; hence, is more liable to burn the foliage. Its use in spraying is the same as Paris green, with the exception that it is advisable to add greater amount of lime.

Bait.—Paris green or London purple 1 ounce, chopped grass or clover 8 ounces, and enough syrup to permit the mass to be worked into balls. These balls are spread around gardens for wire-worms, beetles, crickets, katydids, etc. For grasshoppers and cutworms, mix 40 pounds bran, 15 pounds middlings, arsenic 20 pounds, cheap grade of syrup 2 gallons. Mix in soft water to a paste.

For Insects with Sucking Mouth-parts.—

Kerosene Emulsion.—It is evident that such insects will not imbibe sufficient arsenic placed on a leaf, under the cuticle of which the sucking insects are withdrawing plant juices, to poison them. These insects are destroyed by contact poisons or external irritants, such as kerosene emulsion; a spray composed of soft water 1 gallon, hard soap ½ pound. The soap is dissolved in the water by shaving and then boiling with the water. Remove from fire and add 2 gallons of kerosene; mix thoroughly, add 30 gallons of soft water and apply with kerosene emulsion spraying-pump. To kill, this must reach the bodies of the insects. The substance is penetrating, and enters the breathing-tubes through spiracles of the body, interfering with respiration, and finally choking the insect.

Crude petroleum, applied with emulsion spraying-pump during winter months when leaf buds are closed

and fully dormant. For scale insects, sufficient should be applied to moisten bark of the tree. It is not safe to apply in excess, since there is a liability of injuring the tree. This substance should never be used during the growing season.

FIG. 232. "Kerowater" spray-pump. Designed for mechanically mixing and spraying kerosene and water. The oil and water are mixed and discharged in a milk-like emulsion.

Inaccessible Insects.— Carbon bisulphide, a very volatile and highly inflammable liquid. The vapor is very destructive to animal life. The vapor, being heavier than air, is effective against root insects and insects

in stored grains. For root insects it is poured into holes, which are immediately closed up, causing the fumes to permeate the soil in all directions. For insects in grain bins, pans of this liquid are placed on the top of the grain or stored material. The vapor descends through the stored material. About a teaspoonful is required for each cubic foot of space. Lighted lamps, fire, lighted pipes or cigars must be kept from the building while this method of fumigation is in progress.

Bordeaux Mixture.— This is primarily a fungicide, but has likewise insecticide qualities in certain cases. It is frequently used to good effect at the same time with arsenical sprays for apple scab and other fungous diseases. Paris green is much more preferable in composition with the Bordeaux mixture. The formula for the Bordeaux mixture is as follows:

Sulphate of copper	6 lbs.
Quicklime	4 lbs.
Water	40 gals.

Dissolve the copper sulphate in 4 gallons of water;[1] slake the lime in another vessel; add the milk of lime slowly to the copper sulphate, stirring constantly. Strain through a sieve or coarse-grained gunnysack, and add the remainder of the water. The mixture is ready for use. A simple test to make sure that enough lime is present in the mixture to properly protect the plant, is to place some bright metal substance, such as a knife-blade, in the Bordeaux mixture. If when the blade is withdrawn there is an appearance of copper

[1] The best way to dissolve the sulphate of copper is to suspend it in the water by means of a bag of coffee-sacking. Use the pulverized sulphate.

on the blade, more lime should be added until the knife-blade can be withdrawn untainted. Bordeaux mixture

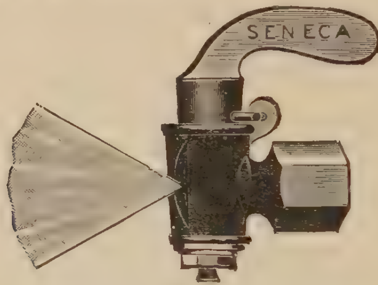


Fig. 233. Seneca spray-nozzle, giving fan-shaped spray covering considerable area, and throwing coarse spray. Adapted to throwing spray some distance.

when used with Paris green solution can be used as so much water; that is, if the amount of water required in mixing up the Paris green solution is 150 gallons, pour in the 40 gallons of Bordeaux mixture and then add the balance or 110 gallons of water, making the 150 gallons of solution of Paris green.

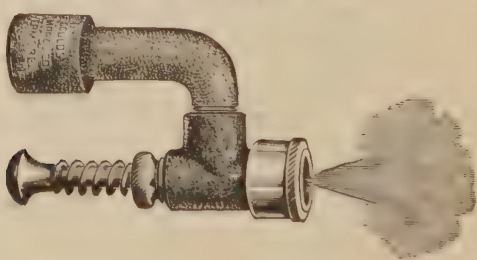


Fig. 234. Vermorel spray-nozzle, affording a conical discharge and fine spray or mist. Adapted to spraying of trees, etc., at close range.

Spraying Machinery.—To secure satisfactory results in spraying, the spray must be kept agitated while being applied, and the application of the spray, as its name implies, should be as a fine mist. The agita-

tion of the material is dependent upon the mechanism of the pump, the formation of the proper spray or mist upon the nozzle, and the force of the pump. The tank or receptacle for the liquid insecticide can conform to requirements. It may be a small bucket, a barrel, or a tank on wheels.

INJURIOUS INSECTS.

Ants.—(*Formica* sp., order Hymenoptera.) Insects frequenting pantries during summer months. Locate crevice from which they come, pour in carbon bisulfide. Ant-hills in lawns can be destroyed by use of same substance poured into holes made in the ant-hill.

Aphids, — Plant-Lice, — Green-Fly.— Order Hemiptera. Minute insects feeding upon tender parts of plants grown both indoors and outdoors.

Remedies.— Kerosene emulsion; tobacco water. In greenhouses, fumigation with smoke from burning tobacco stems.

Apple. —Apple-Tree Borer, Round-headed.—(*Saperda candida* Fabr.; order Coleoptera.) In the fall the bark of infested young trees discolors near the base of the trunk. The larva lies beneath this discoloration. In the spring the bark cracks, and reddish wood dust drops. The adult is a pale-brown beetle, with two creamy white stripes the full length of the body. The antennæ are longer than the body. The eggs are laid in June and July. The larva spends the season in the trunk of the tree, boring during the summer months. The full-grown larva is over an inch long, fleshy, footless, and has a chestnut-brown head.

Preventive.— Heavy coat of whitewash on trunks in

latter part of May. Wrapper of mosquito netting around the lower portion (about two feet high) of trunk, tied at the top and hilled up against at the bottom. Whitewash upper part of trunk.

Remedy.— Dig out borers with a sharp knife and strong wire probe.

APPLE-TREE BORER, FLAT-HEADED.—(*Chrysobothris femorata* Fabr.; order Coleoptera. A shining greenish black beetle, a little less than half an inch long. The larva can be found in trunk and larger branches. May be detected by discolored spots, cracking of bark, or appearance of sawdust. Mature larva, pale yellow, head end greatly enlarged and flattened.

Preventive and Remedy.— Same as for Round-headed borer.

APPLE FLEA BEETLE.—(*Graptodera foliacea* Lec.; order Coleoptera.) Beetle one-fifth inch long, feeding upon leaves.

Remedy.—Arsenites.

BARK-LICE (especially *Mytilaspis* sp., *Aspidiotus* sp., *Chionaspis* sp.; order Hemiptera). Mite-like insects, crawling in early spring; later becoming stationary, and secreting a waxy scale. (See page 187.)

Preventive.— Plant unaffected trees.

Remedy.— Spray with kerosene emulsion during growing season; with crude petroleum during dormant season.

BUD MOTH.—(*Tmetocera ocellana* Fabr.; order Lepidoptera.) A minute moth, the larvæ of which destroy the flower-buds of apples, pears, plums, etc.

Remedy.—Arsenite sprays applied as buds begin to open, and then ten days later.

Canker Worm.—(*Paleacrita vernata* Peck.; order Lepidoptera.) The "measuring-worm" larva, about an inch long, feeds upon the leaves. When disturbed it suspends itself by a thread.

Preventive.—Bands smeared with tar, printers' ink, or a similar harmless adhesive substance, placed around the trunks of the trees, about first of February, to prevent the ascent of wingless parent female.

Remedy.—Thorough spraying with arsenites; very effective.

Codling Moth.—(*Carpocapsa pomonella* Linn.; order Lepidoptera.) The larva a whitish worm, found feeding in or toward the core of the apple. Generally two broods. For adult, see Fig. 104.

Remedies.—Thorough spraying with arsenites, when blossoms have fallen; then again ten days later. See pages 129, 131. Can be used profitably with Bordeaux mixture for apple scab. Two broods. Larvæ and chrysalids will secrete themselves in burlap, cloth or paper bands in forks of trees, or around trunk. These can be destroyed every seven to nine days.

Fall Web Worm.—(*Hyphantria cunea* Drury; order Lepidoptera.) A hairy caterpillar varying in color from gray to pale yellow or bluish black. It feeds upon the leaves of many trees, and lives in webs.

Remedies.—Remove the webs; crush or burn occupants. Spray with arsenites.

Root Louse.—(*Schizoneura lanigera* Hausm.; order Hemiptera.) A small insect whose presence on the root is manifested by knotty swellings of roots and the presence of bluish white "wool." In another form

the insect feeds upon the branches. The woolly white covering is present here also.

Preventive.— Plant unaffected trees.

Remedies.— Hot water. Roots of nursery stock may be dipped in water having a temperature of 120° to 150° F. Kerosene emulsion or tobacco-dust poured in trenches around the roots of orchard trees.

TENT CATERPILLARS.— (*Clisiocampa Americana* Harris; order Lepidoptera.) Hairy blackish larvæ about two inches in length, white stripe along back, feeding on the leaves in May and June, emerging from silken webs or tents in which they spend the time not occupied in feeding.

Remedies.— Cut off egg-covered twigs during winter and early spring. Burn out or remove nests. Spray with arsenites.

TUSSOCK MOTH. — (*Orgyia leucostigma* Sm. and Abb.; order Lepidoptera.) A bright yellow caterpillar, with red markings about an inch long; very hairy.

Remedies.— Collect foamy egg-masses in fall. Spray with arsenites.

Apricot.— PIN-HOLE BORER.— (*Scolytus rugulosus* Ratz.; order Coleoptera.) See under Peach.

PLUM CURCULIO. See under Plum.

Bean.—BEAN WEEVIL OR BEAN BUG.—(*Bruchus obtectus* Say; order Coleoptera.) Very similar to pea weevil. A small brown-black beetle. The beetles appear in fall and spring, and lay eggs in young pods. The larvæ or grubs live in growing seeds.

Remedies.—As soon as mature beans are picked, place them in temperature of 145° F. for an hour;

this does not injure the seed. The beans may also be placed in tight box or bin and fumigated with carbon bisulphide.

Bag Worm or Basket Worm.—(*Thyridopteryx ephemeræformis* Haw.; order Lepidoptera.) The bags covered with short bits of sticks, empty or containing the female egg-sac, conspicuous during winter months. The larva feeds upon both evergreen and deciduous trees.

Remedies.—Arsenites. Hand-picking.

Bark-Lice. See under Apple.

Blackberry.—Cane Borer.—(*Oberea bimaculata* Oliv.; order Coleoptera.) Small slender black beetle. It makes two girdles, an inch apart, near the tip of a cane, and lays egg between girdles. The larva bores down the cane.

Remedy.—When cane-tip wilts, cut off below lower girdle, and burn.

Rootgall-Fly.—(*Rhodites radicum* Sacken; order Diptera.) The small larva causes galls on roots of blackberry, raspberry, and rose. The bush appears sickly. Female dies. Do not confound with true root-galls.

Remedy.—Dig up and burn badly affected plants.

Snowy Tree Cricket.—(*Oecanthus niveus* Serv.; order Orthoptera.) Small whitish insect; cricket-like. Punctures canes to deposit eggs. (See Figure 36.)

Remedy.—Burn infested canes in winter or very early spring.

Blister Beetle.—(Family Meloidæ; order Coleoptera.) Soft, slim, long-necked beetles; some black

and others gray or striped. Feeds upon leaves of trees and many garden plants.

Remedy.—Arsenites.

BUFFALO MOTH.— Buffalo Beetle. (*Anthrenus scrofulariæ* Linn.; order Coleoptera.) The adult is a small brick-red and white beetle, about one-quarter inch long. The larvæ are small, dark-colored, hairy creatures, infesting carpets and woolen goods. The larvæ do the damage.

Remedies.—Use rugs instead of carpets. Rugs to be sunned frequently. Infested carpets should be treated likewise. The floors under them should be thoroughly scalded. Infested woolen may be placed in tight boxes and fumigated with carbon bisulphide.

Cabbage.—CABBAGE WORM or CABBAGE BUTTERFLY. (*Pieris rapæ* Linn.; order Lepidoptera.) Larvæ an inch long, green, black and yellow markings. Feeds upon the leaves and heads. Two broods.

Remedies.— Hot-water spray at temperature 140° to 160° F. Kerosene emulsion. Salt water sprinkled into the head.

GREEN LETTUCE WORM.– (*Plusia brassicæ* Riley; order Lepidoptera.) Pale green larva over an inch long, faint stripes. Feeds upon leaves of many plants, such as celery, cabbage, and lettuce.

Remedies.— Kerosene emulsion. Hot water.

HARLEQUIN CABBAGE BUG.—(*Murgantia histrionica* Hahn.; order Hemiptera.) Bug about half-inch long, orange dots and stripes over blue-black ground; somewhat gaudy. Two to six broods.

Remedies.—Hand-picking. Insects will secrete them-

selves in piles of rubbish. In fall, place piles of rubbish in patch; burn early in the winter.

LICE.—(Family Aphidæ; order Hemiptera.)

Remedy.—Kerosene emulsion.

MAGGOT.—(*Phorbia brassicæ* Bouché; order Diptera.) The maggot, a fly larva, eats its way into the crown and roots of young cabbage, cauliflower, radishes, etc.

Remedies.—For cabbage and cauliflower, pour teaspoonful carbon bisulphide in hole close to roots of each plant. Burn all infested plants.

The "club-root" of cabbage is not due to this, but is a fungous disease.

Cauliflower.—CAULIFLOWER OR CABBAGE WORM. See under Cabbage.

MAGGOT. See under Cabbage.

Celery.—GREEN LETTUCE WORM. See under Cabbage.

Cherry.—CANKER WORM. See under Apple.

PLUM CURCULIO. See under Plum.

CHINCH-BUG. See under Corn.

CLOTHES MOTH.—(*Tinea pellionella* Linn.; order Lepidoptera.) Small cylindrical rolls or cases, in each of which is a small, soft-bodied larva. This feeds on woolens, hair-cloth, fur, and feathers. The adult is a very small light-brown moth; wing expanse about one-third of an inch. (See Fig. 120.)

Preventive.—After thorough cleansing, airing, sunning of woolens, furs, etc., through May and June,

pack away for summer wrapped in stout paper, to prevent entrance of some belated female.

Remedies.— Thorough sunning of goods likely to be infested in May and June. Goods which can be readily placed in tight chests can be fumigated with carbon bisulphide.

Corn.— CHINCH-BUG.—(*Blissus leucopterus* Say; order Hemiptera.) A small dark-colored bug; wings white, with dark triangular spot on each. The bugs frequently collect on corn-stalks and leaves so as to blacken a part of the plants. They frequently obtain their first spring food in wheat, millet, and other cereals, forsaking them for the corn after the other cereals are harvested.

Preventive.— Burning all rubbish in fall. Rotation of crops.

Remedy.— Ditching. (See Fig. 109.)

CORN-ROOT WORM.—(*Diabrotica longicornis* and *D. 12-punctata*; order Coleoptera.) Stalks of corn stunted; fall over easily. Examination shows many roots severed. Plain greenish-brown beetles, and yellowish beetles with twelve black spots on back; to be found in the shooting tassels.

Preventive.— Rotation of crops.

CORN BILL-BUGS.—(*Sphenophorus* sp.; order Coleoptera.) Black or brown in color; one-fourth to one-half inch in length; back marked with longitudinal ridges. Adults attack corn planted after timothy or sod, hiding during day at base of corn plants, boring round holes in stem.

Remedy.— Fall plowing of land.

Grain Beetle or Grain Weevil.—(*Silvanus surinamensis* Linn; order Coleoptera.) Reddish brown beetle about one-tenth of an inch in length; feeds in stored corn or other grain.

Remedy.— Bisulphide of carbon. .

Angoumois Grain Moth.— (*Gelechia cerealella* Oliv.; order Lepidoptera.) The larva burrows within kernels of stored grain, making small round hole. See Figure 108.

Remedy.— Carbon bisulphide.

Corn Worm.— See under Tomato.

Corn-root Louse.—(*Aphis maidi-radicis* Forbes; order Hemiptera.) Masses of small bluish lice found feeding on roots of corn plants.

Remedy.— Thorough spring culture to keep down weeds upon which lice can also live, and to encourage the more vigorous growth of the corn.

Grasshoppers.—(Family Acrididæ; order Orthoptera.) For description, see pages 3–12.

Preventive.— Disk-harrowing in early spring, where grasshoppers deposit their eggs the fall before.

Remedies.— Arsenites in bait. When grasshoppers are entering a new field, a strip of the field at the place of entrance may be sprayed with arsenites, to be fed upon as they enter. Catching with "hopperdozer."

Cucumber. — Cucumber or Pickle Worm.—(*Eudioptis nitidalis* Cram.; order Lepidoptera.) Larva about an inch long, yellowish white, slightly green, boring into cucumber. There are two broods.

Remedies.— Hand-picking when they first appear. Infested fruit to be destroyed.

Melon Worm.—(*Eudioptis hyalinata* Linn.; order Lepidoptera.) Larva about an inch long, slightly hairy, yellowish green. Feeds on melon leaves and eats holes into the melon, cucumber, and squash. Two broods at least.

Remedies.—Arsenites applied very early in the season.

Spotted Cucumber Beetle.—(*Diabrotica 12-punctata* Oliv.; order Coleoptera.) Yellow and black spotted beetle, one-fourth inch long; feeds on leaves and fruit. The larva sometimes injures corn root. (See Corn.)

Preventive.— Cover with frames of mosquito netting.

Remedy.— Tobacco powder liberally applied. Arsenites in flour. Ashes sprinkled on plants from two to three times when they are wet.

Striped Cucumber Beetle.— (*Diabrotica vittata* Fabr.; order Coleoptera.) The larva of beetle with black stripes about one-fourth inch long. The beetle feeds on the leaves; the larva, about one-eighth inch long, feeds on roots. There are two broods.

Preventives and remedies same as for Spotted Beetle.

Currant.— Borer.—(*Sesia tipuliformis* Linn.; order Lepidoptera.) Whitish larva, which bores into currant canes and into gooseberry, spending winter there.

Remedy.— Burn all affected cane in fall and early spring. Infested canes are made manifest by lack of vigor and stiffness.

Currant Saw-Fly.—(*Nematus ventricosus* King; order Hymenoptera.) A yellowish green larva, about three-fourths inch long, and feeds upon the leaves. Two to four broods.

Remedies.— Arsenites thoroughly applied to check first brood. Should be applied before larvæ leave the lowest leaves. Later broods are more difficult to deal with; hence, the first brood should be promptly checked.

Carpets.— BUFFALO BEETLE. See under B.

CLOTHES MOTH. See under C.

CODLING MOTH. See under Apple.

Clover.— CLOVER HAY WORM.— (*Asopia costalis* Fabr.; order Lepidoptera.) A larva which attacks the dry or partially dry clover.

Remedy.— Clean mows out before storing new hay; salt the first two or three feet of newly stored hay.

CLOVER SEED MIDGE.—(*Cecidomyia leguminicola* Lint.; order Diptera.) Larva feeds upon the forming seed, destroying it.

Remedies.— Cut early crop when in full head, and depend upon second crop for seed. The flies oviposit in flowers of first crop. Fall plowing in infested fields. Use lime and kainit in fall after crop is off.

CUT-WORMS.—(*Agrotis* sp. and others; order Lepidoptera.) Soft brown to grayish worms feeding upon tops and crowns or even roots of plants.

Remedy.—Arsenical baits placed about in the evening. In garden plots, dig deep narrow holes near plants to be protected. The worms will fall in and cannot escape. Worms frequently remain hidden during the day.

CUT-WORMS, CLIMBING.— Several varieties. Worms climb trees at night and eat off the buds.

Preventive.— Cotton batting banded about the tree; top of band turned down, and worms cannot climb over.

Remedies.—Arsenical baits.

Elm.— CANKER WORM. See under Apple.

BAG WORM. See under B.

ELM-LEAF BEETLE.—(*Galleruca xanthomelæna* Schr.; order Coleoptera.) A small beetle that eats the green matter from elm leaves, giving the tree a scorched appearance.

Remedy.—Arsenites.

FOUR-STRIPED PLANT-BUG.—(*Poecilocapsus lineatus* Fabr.; order Hemiptera.) Bright-yellow bug, with black stripes. It punctures the young leaves and shoots of a number of plants.

Remedy.— Kerosene emulsion.

Gooseberry.— CURRANT BORER. See under Currant.

FOUR-STRIPED PLANT-BUG. See under F.

GRAIN MOTH. See under Corn.

GRAIN WEEVIL. See under Corn.

Grape.— APPLE-TREE BORER. See under Apple.

CURCULIO.—(*Craponius inæqualis* Say; order Coleoptera.) A small black or grayish larva; infests the grape in June and July. Discolors the berry around the little black hole of entrance.

Remedies.— Jar the beetle off in sheets, as with the plum curculio.

GRAPE SLUG OR SAW-FLY.—(*Selandria vitis* Harris; order Hymenoptera.) Larva yellowish green; about one-half inch long; feeds upon the leaves. Two broods.

Remedies.— Arsenites.

GRAPEVINE FIDIA.—(*Fidia viticida* Walsh; order

Coleoptera.) A short, broad beetle; riddles the leaves in June and July. The larva attacks the roots of grapes — preferably the Worden.

Remedies.— Strong arsenic sprays for the beetles; the larvæ on roots can be destroyed by bisulphide of carbon.

Grape Flea-Beetle.—(*Graptodera chalybea* Illig.; order Coleoptera.) A blue metallic beetle, one-fourth inch in length. Feeds upon buds and tender shoots in spring.

Remedies.—Arsenites.

Grapevine Sphinx.—(*Ampelophaga myron* Cramer; order Lepidoptera.) A large green caterpillar, with yellow spots and stripes. At maturity is about two inches in length. Bears a horn at the posterior extremity, and feeds upon the leaves and young grapes. Two broods.

Remedies.— Hand-picking. Arsenites to be used in the early season.

Root Borer. See Grapevine Fidia.

Snowy Cricket. See under Blackberry.

Leaf-Hopper.—(*Erythroneura vitis* Harris; order Hemiptera.) A small insect, less than one-tenth inch in length. Feeds upon leaves, and makes them appear scorched.

Remedies.— Kerosene emulsion; small bonfires built at night in vineyard attract many to them. Clean culture in the fall, to prevent collection of rubbish for insects to hibernate in.

Green-Fly. See Plant-Lice.

Green Striped Maple Worm.—(*Anisota rubicunda* Fabr.; order Lepidoptera.) A yellowish green, longi-

tudinally striped naked insect, about one and a half inches long. Feeds on leaves of maple. Two broods.

Remedies.— Spray with arsenites, early in the season. Insect has several parasites which keep it in check. Many birds prey upon it.

House Plants.— See Plant-Lice, Scale Insects, and Red Spider.

HESSIAN FLY. See under Wheat.

HORN-FLY OF CATTLE.— (*Hæmatobia serrata* R. Desv.; order Diptera.) A small black fly, about one-sixth of an inch long, tinged with brown and gray. Characteristic habit is to cluster about the base of the horn.

Preventive.— Greasy substances, such as tallow or fish oil, will keep insects away from animals for several days. Spraying the animals with kerosene emulsion.

JUNE BUG. See May Beetle.

LEAF-CRUMPLER.— (*Phycis indiginella* Zeller; order Lepidoptera.) Brown larva, found within the folded leaves of the various kinds of plants.

Remedy.— Spray with arsenite before the larvæ conceal themselves within the folded leaves. Gather the folded leaves after the larvæ have pupated, and burn them.

Lettuce.— APHIS OR GREEN-FLY.— A plant-louse which thrives on lettuce growing under glass.

Preventive.— Tobacco-dust thrown on leaves of plants when aphis first appears. A better method is to fumigate with tobacco.

GREEN LETTUCE WORM. See under Cabbage.

LICE. See under Plant-Lice.

May Beetle or June Bug.—(*Lachnosterna fusca* Frohl.; order Coleoptera.) A large familiar brown beetle, frequently heard buzzing about lamps at night. Feeds upon leaves of several varieties of trees. The common white grub, found when turning the soil, is the larval stage of this beetle. This grub frequently damages strawberries.

Remedies.—Use arsenites for beetle, and grubby plots can be freed by plowing to expose the grubs to poultry and field birds. The hogs will likewise clear the ground. Do not plant strawberries in land where these grubs are abundant.

Mealy-Bugs.—(*Dactylopius adonidum* Linn.; order Hemiptera.) White scale insects, which feed upon greenhouse plants.

Remedies.—A small stream of water generally drives them away from greenhouse plants. House plants may be washed in soapsuds or the insects can be removed from tender plants with an old toothbrush.

Maple.—Maple Worm. See under Green Striped Maple Worm.

Fall Web Worm.—(*Hyphantria cunea* Drury; order Lepidoptera.) Caterpillars feeding in swarms within large webs in late summer and early fall. Remove the web-infested limbs, and burn or crush the worms thereon. If it is objectionable to remove the infested limbs, spray the populous web thoroughly with kerosene emulsion.

Box-Elder Bug. See page 184.

Bag Worm. See under B.

Maple Scale.—(*Pulvinaria innumerabilis*; order

Hemiptera.) A good-sized brown scale insect. During the summer months a large cottony egg-sac appears from the posterior end of the female.

Remedy.— Spray with crude petroleum, during the dormant season.

Mosquito.—(Family Culicidæ; order Diptera.) A long, slender fly. The females have strong, piercing mouth-parts used in piercing the cuticle of man and other animals.

Preventive.— Keep cisterns and rain-barrels well covered. The surface of all ponds and small pools of water in the vicinity, when not drained, should be coated during the breeding season with kerosene, since these insects breed in rain-water.

Pea.— Pea Weevil.—(*Bruchus pisi* Linn.; order Coleoptera.) Very similar to Bean Weevil. See under B. Same remedies.

Peach.—(*Aphis persicæ* Smith; order Hemiptera.) A dark-brown plant-louse, attacking tops and roots. More abundant in sandy lands.

Remedies.— Kerosene emulsion for tree colonies. Tobacco-dust placed in trench around roots of trees for root colonies.

Flat-headed Borer. See under Apple.

Fruit Bark Beetle or Pin-hole Borer.—(*Scolytus rugulosus* Ratz.; order Coleoptera.) A black beetle which bores into trunks and branches of peach, plum and apricot trees. It is about one-tenth of an inch in length.

Remedies.— Burn the affected trees, since this beetle shows preference for weak or sickly trees. Keep trees strong and healthy.

Peach-Tree Borer.—(*Sannina exitiosa* Say; order Lepidoptera.) Larva whitish, three-fourths inch long at maturity; bores into crown and upper roots of peach, causing gum to exude.

Preventive.— Mounding, *i. e.*, mound up earth about a foot high around the tree early in the summer, and remove late in fall. The moth, then, lays eggs at mound top, and the larvæ die from exposure. Only fairly satisfactory.

Remedy.— The most reliable means of combatting this insect is to dig out the borers in the late fall and early spring.

Plum Curculio. See under Plum.

Pear.—Apple-Tree Borer. See under Apple.

Bud Moth. See under Apple.

Codling Moth. See under Apple.

Flat-headed Borer. See under Apple.

Pear-Leaf Blister.— (*Phytoptus pyri* Scheuten.) A very small mite, causing blisters on the leaves. The mites spend the winter under the bud scales.

Remedy.— Spray with kerosene emulsion.

Pear-Tree Borer.—(*Sesia pyri* Harris; order Lepidoptera.) Larva whitish; feeds under bark.

Remedy.— Dig out the larva with a knife.

Psylla.—(*Psylla pyricola* Forst.; order Hemiptera.) Resembles plant-louse; infests pear twigs when fruit is setting. Exudes "honeydew" in which grows a fungus. This fungus frequently gives the pear twigs a sooty appearance.

Remedy.— Repeated sprayings with kerosene emulsion, beginning at time leaves are expanding.

Round-headed Borer. See under Apple.

Plum.— Bud Moth. See under Apple.

Canker Worm. See under Apple.

Curculio.— (*Conotrachelus nenuphar* Herbst.; order Coleoptera.) The larva is a whitish grub, which feeds on the fruit.

Remedies.— Jar the trees with padded mallet, in the early morning, beginning when the trees are in bloom and continuing four or five weeks. Place sheets under the tree, to catch the beetles as they fall; gather and destroy. The sheet or canvas may be arranged upon a frame in the form of an inverted umbrella, with one section left out to admit the tree; and this structure may be pushed around from tree to tree on wheels.

Flat-headed Borer. See under Apple.

Plum-Gouger.—(*Coccotorus scutellaris* Lec.; order Coleoptera.) The larva feeds on the kernel. The beetle bores a round hole in the plum. The curculio makes a crescent mark.

Remedy.— Same as for Curculio.

Plum Scale.--(*Lecanium* sp.; order Hemiptera.) A large brown scale insect.

Remedy.— Spray with kerosene emulsion, or in winter months with crude petroleum.

Potato. — Colorado Potato Beetle.—(*Doryphora decemlineata* Say; order Coleoptera.) Both beetle and larva feed upon the leaves.

Remedies.—Arsenites.

Stalk Weevil.—(*Trichobaris trinotata* Say; order Coleoptera.) The larva bores into the stalk of the potato near the ground.

Remedy.— Burn all infested vines.

Quince.— Round-headed Borer. See under Apple.

Raspberry.— Cane Borer. See under Blackberry.

Root Borer. See under Grape.

Rootgall-Fly.—(*Rhodites radicum* Sacken; order Diptera.) The larva produces galls on the roots of the raspberry, blackberry, seriously affecting the health of the plant. These swellings must not be confounded with the true root-galls found on raspberry, blackberry, apple, and peach. This root-gall is a fungous disease, especially noticeable in nursery stock.

Remedy.— The best remedy thus far seems to be the destruction of all infested plants.

Snowy Tree Cricket. See under Blackberry.

Red Spider.—(*Tetranychus telarius* Linn.) A small red mite, found on plants both in greenhouse and outdoors.

Remedy.— Strong streams of water from a hose. kerosene emulsion.

Rose.— Rootgall Fly. See under Raspberry.

Mealy-Bug. See under M.

Rose Slug.—(*Selandria rosæ* Harr.; order Hymenoptera.) A slug-like worm, soft greenish or yellowish, about one-half an inch long. It eats large patches in the upper surface of rose leaves. The leaves appear scorched, and drop off. Feeding is done by night, and the slugs rest on the under side of the leaves during the day.

Remedy.— Forcible stream from a hose will wash off many. Spray with arsenites.

San Jose Scale.—(*Aspidiotus perniciosus* Comst.;

order Hemiptera.) The very small circular scale not easily detected; lives upon a large number of deciduous trees.

Remedies.— Frequent applications of kerosene emulsion during summer. Several applications of crude petroleum during the dormant season. Avoid infested stock.

Scale Insects. See under Plant-Lice.

Squash.— Borer.— (*Melittia ceto* Westw.; order Lepidoptera.) The larva bores into the root or crown of the squash and other plants of this family. The parent moth flies by day.

Remedies.—When vines begin to run, cover the fourth, fifth or sixth joints with earth, so that they may take root and aid in supporting the plant.

Squash Bug.—(*Anasa tristis* De Geer; order Hemiptera.) A flattened, rusty, ill-smelling bug, one-half inch long; pierces leaves with its sucking beak. Leaves become yellow and die.

Remedies.— The insects will collect at night under boards laid near the hills, and can be crushed. A thorough spray with kerosene emulsion will kill the young bugs.

Strawberry.— Crown Borer.—(*Tyloderma fragariæ* Riley; order Coleoptera.) A white grub; bores into the crown of the plant during the middle of summer.

Remedy.— Burn over field after fruit is gathered. If this is unsuccessful, dig up plants and burn them.

May Beetle. See under M.

Leaf Roller.—(*Phoxopteris comptana* Fröhl.; order Coleoptera.) Larva about one-half inch long; feeds on

the leaves, protecting itself by rolling them up and tying with threads of silk. Two broods.

Remedies.— If arsenites are applied before the leaves are rolled, the caterpillar may be destroyed; if not, after fruit is off the leaves of the strawberry plants should be mowed over, and the stalks and leaves burned.

ROOT BORER.— (*Anarsia lineatella* Zeller; order Lepidoptera.) A whitish borer, boring into crown of plant late in season and remaining there over winter.

Remedy.— Burn the plants.

ROOT LOUSE.—(*Aphis Forbesii* Weed; order Hemiptera.) In the latter part of the season lice appear in great numbers on the crowns and roots of the plants.

Remedies.— Rotation of crops.

SAW-FLY.— (*Emphytus maculata* Norton; order Hymenoptera.) A greenish larva, about three-fourths of an inch long; feeds upon leaves. Two broods.

Remedies.— Spraying with arsenites for second brood.

Sweet Potato.— SAW-FLY.—(*Schizocerus ebenus* Norton; order Hymenoptera.) A small larva, which feeds upon the leaves.

Remedies.— Spray with arsenites.

Tomato.— FRUIT WORM.—(*Heliothis armiger* Hub.; order Lepidoptera.) A pale-green or brown larva, about an inch long; faintly striped. Feeds upon the tomato fruit. The same species is found feeding in the head of the ears of sweet corn. Also attacks cotton.

Remedy.— Hand-picking.

TOMATO WORM.—(*Phlegethontius celeus* Hbn.; order Lepidoptera.) This large green worm is occasionally seen upon the leaves and stems of the tomato. By

reason of its size it is an attractive prey for parasites, and seldom becomes abundant enough to become serious.

Remedies.— Hand-picking. Arsenites.

Wheat.— Chinch-Bug. See under Corn.

Hessian Fly.—(*Cecidomyia destructor* Say; order Diptera.) During the winter, small brown seed-pods ("flax-seeds") may be found in the plants near the roots. These are the chrysalids. Small black two-winged flies emerge from these in April and May. The young whitish grubs attack the stalks near the base. From two to four broods. The fall brood lays its eggs before the 20th of September. It attacks rye and barley.

Remedy.— Burn or plow under stubble immediately after harvest, and destroy summer brood which is then in "flax-seed" stage. Keep down the volunteer wheat; postpone sowing the wheat until after the 20th of September, when eggs will have been deposited on other plants. Fertilizers added in spring materially aid infected wheat to tiller, and thus outgrow the injury.

Fall Army Worm.—(*Laphygma frugiperda* Smith and Abb.; order Lepidoptera.) A pale-brown caterpillar; feeds upon wheat, corn, rye, and other succulent plants, during September and October. Frequently travel together in the same direction in quest of food,— whence the name.

Remedy.— Late fall plowing of fields where pests have been; crushing caterpillars with the roller. Wheat-fields eaten off in fall are not necessarily destroyed.

Grasshopper. See under Corn.

White Ants or Termites.— These insects frequent

orchards, especially those containing old stumps or rubbish. More common in Southern States.

Remedy.— Carbon bisulphide. Washing trunk of infested tree with a mixture of kerosene emulsion and arsenites.

WIRE WORM.—(Family Elateridæ.) These are slim, brown larvæ, which feed upon the roots of various plants. They are the immature forms of the "click beetle."

Remedy.—Arsenical bait of fresh clover or sweetened corn-meal dough. Fall plowing. Rotation of crops.

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